A note before getting into the crystal radio story.

After I experimented with the Heathkit CR1 crystal radio and built the radio described below, I got out my old regenerative radio I made in 1958 and was once again astounded by how much better it performed than even the CR1. I have now come to the conclusion that anybody who wants to build an ultra-simple radio really should consider my Armstrong "Crystal" Radio first.

Recently added to my website

If you are looking to build a little radio that is as simple and as easy to build as a basic crystal radio, but performs many, many times better than even the best and most complex crystal radio, I highly recommend building my Armstrong "Crystal" Radio . There is a link to the Armstrong Radio project at the very bottom of the following crystal radio story. Please scroll down for the link, but I invite you to look over the pictures and headings to see if there isn't something that might interest you.

If you are determined to build a tiny crystal radio with no amplification or are just interested in reading about my crystal radio and how I built it for its entertainment and especially for its educational value, please read on.

A miniature, but selective and high performance CRYSTAL RADIO KIT

The description of a project intended for advanced science students and hobbyists and containing personal and controversial opinions and thoughts that you can skip

by John Fuhring

My tiny, but selective and sensitive crystal radio.

Introduction

Not long ago I rebuilt and put into operation a Heathkit CR1 crystal radio. I hadn't built a crystal radio since I put together my first radio when I was 10 years old, nor had I used a crystal set since I was 13. During the period of the mid to late 1950s, I owned at least three crystal radios of varying performance. With the Heathkit, I now had a crystal radio that performed far better than any of the radios that I remember using as a kid and once again I was struck by the magic of building and operating such an utterly simple and basic radio receiver. Suddenly it occurred to me that it might be fun to try my hand at designing and building my own crystal set from scratch. Besides that, a former grammar school teacher I'm friends with suggested to me that school aged kids would have a lot of fun learning about radio theory if they could build a working crystal radio and he asked me to come up with such a radio.. Of course, this strongly reminded me of how, in 1955, my aunt gave me crystal radio kit to build and how that experience lead to my lifelong interest in radio and my career in electronics. The memories flooded back and awoke in me that desire I think we all have and that is to pass along to others those things that have helped us.

Well, I have given a lot of thought to crystal radios lately and I have concluded that the ultra-simple, very poorly performing crystal radios that most teachers have their classes construct are just not worth building. Rather than try to force kids who are just not interested in how their technological world actually works -- and after all, most of us only want to use technology, not design or even understand it -- I think that building a crystal

set should be limited to only those students who show a genuine interest in this sort of thing. In my opinion, the only students who should build something like this are the kids I call a school's "the scientific elite" (but who others would call "the nerds"). I think that building a crystal radio should be done as an individual science project, but not as a class project. However, and this is most important, any radio anybody builds should be worth building and should at least approach the performance of the Heathkit CR1.

It soon became my goal to design a low cost, but good performing little radio that would not only be easy and practical to build, but would be something a young person would be proud of and want to keep and use. Of course, this applies to adults too, even old geezers like me. So, the following paragraphs will describe the little radio I have come up with. Please be aware that because the little radio is very compact, it requires some very careful, precision soldering using a dangerously hot soldering iron. Additionally, winding 7 feet of wire on each of two toroid forms is tedious and requires manual dexterity and skill. Because of these difficulties, I am very much of the opinion that this little radio is not a project for very young (under 12) kids. You must use your own judgment regarding whether or not this project is practical for you or your student(s) to build.

Design considerations for a simple but good performing crystal radio

Before I begin the technical phase of this article, please note that I performed several experiments with different kinds of wire and different detectors before I finalized the design that I will be presenting. What I'm presenting here is how and with what materials and components I think a builder should use for optimum performance.

Here then are my design criteria:

Any crystal radio worth building should have good selectivity. That means that you should be able to hear a station without the audio of an adjacent station in there too. Of course, the selectivity of any crystal radio is such that, if you listen closely, you will always hear a powerful nearby station in with your station, but that unwanted signal should be very faint.

Any crystal radio worth building should have good sensitivity. That means that you should be able to hear even relatively distant and weak stations. Of course, crystal radios have no amplification and depend entirely on capturing enough radio energy to operate the earphone to produce sound waves. The radio must have efficient tuning coils, tuning condensers and a efficient detector so that the tiny amounts of energy that is picked up by the antenna is not wasted or lost in the radio any more than absolutely necessary. If the radio is designed properly with low-loss components, the human ear, with its amazing ability to hear even very low energy sound waves, will do the rest.

Any crystal radio worth building should be in a pleasing enclosure or chassis that makes mounting the components easy, makes connecting to the antenna and ground easy, makes it easy to plug in the earphones and makes operating the tuning controls convenient. When the project is complete, the builder should have a radio that looks like a radio and something (s)he is proud of and proud to show to others.

Certainly, the Heathkit CR1 fits these criteria extremely well and I think that the little radio I will present on this page fits the criteria well too. In some respects, if I may say so myself, my radio fits some of them even better than the CR1.

An update as of June 21, 2017

After exchanging some email with a reader, I have revisited my little project and have rethought some things. I then went in and made some simple modifications and I am extremely pleased with the results. The modifications work so well, I am redrawing the schematics and the improved version of this radio is what I will present.

Building the radio

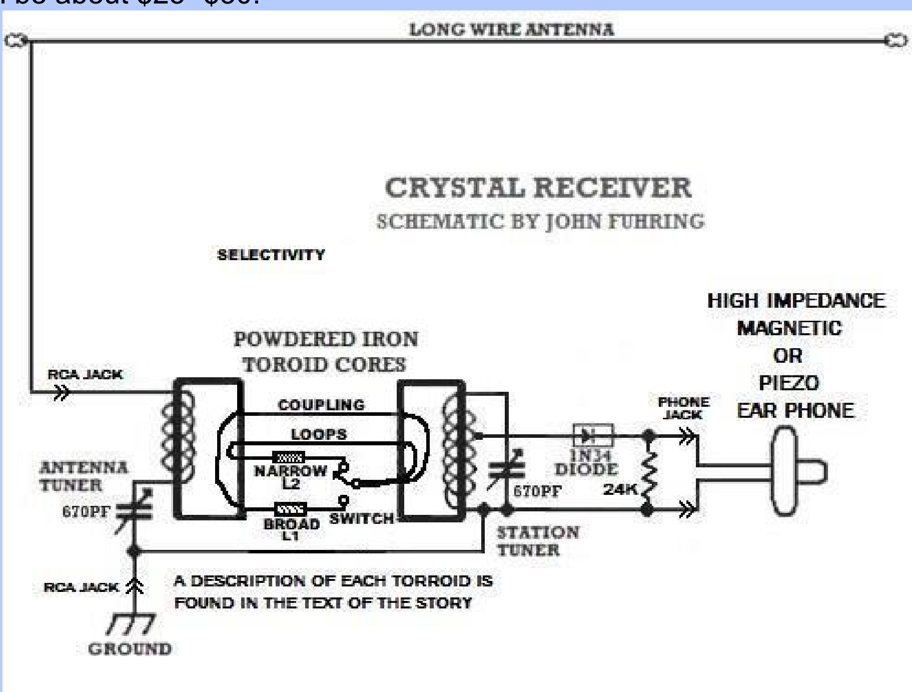
List of parts:

1) Two each, T80-15 toroid cores. **
2) Two each, dual section 335 X 335 PF variable tuning capacitors (670 PF total each). ***

3) Two each, knob and shaft extension for the above tuning capacitors.
4) Four each, 2.5 X 5 MM countersink screws to mount the tuning capacitors.
5) One 1N34A diode.
6) One piezoelectric earphone (or high Z magnetic earphones) with a miniature phone plug.
7) One panel mount miniature phone jack (to match item 6 above).
8) One, panel mount RCA type jack.
9) One RCA type plug with item 10 wire leads soldered to it to match item 8 above.
10) Two each, 6" 20 Ga. colored (red & black) insulated wire leads for the antenna and ground. (Use black for ground)
11) Two each, small alligator clips. Solder to the end of the above insulated wires for antenna and ground connections.
12) Two pieces of 40/46 litz wire each 7 feet long. No. 30 (or larger) magnet wire can be used but not recommended.
13) One 6" section No. 24 ga magnet wire for the interconnecting link. Litz wire can be used, but stiffer wire may be preferred.
14) One 24,000 ohm (24K) resistor. A 1/4 or 1/8 watt resistor is recommended to more easily fit in the limited space.
15) One L1 coil made of 6 turns of litz wire wrapped around a wooden match stick. Cut off unused wood.
16) One 12 coil made of 12 turns of litz wire wrapped around a wooden match stick. Cut off unused wood.
17) A single pole double pole miniature switch.
18) A small tube of RTV type adhesive. Do not use an adhesive that becomes hard because you may want to change coils.
19) Metal or plastic box to mount the components.
20) Antenna 60 + feet or as long as practical and mounted as high up as practical.

** Use only toroids made with the -15 material. Other cores will greatly complicate winding and/or degrade performance. Smaller cores may be used, but the number of turns will have to be adjusted.
*** You can use smaller values for finer tuning. For large chassis projects, conventional 360 PF air variable condensers are excellent and will probably give you higher 'Q' and lower signal losses. Ganging the two sections of the miniature condensers as I have done gives a greater tuning and antenna trim range. Since the tuning of a crystal radio is so broad, condensers ganged this way are still easy to adjust for maximum signal and minimum interference from stations off to the side.

Total cost of parts will be about $25 -$30.



Crystal radio schematic diagram.

Notes

I originally wound the coils with No. 30 magnet wire, but was dissatisfied with the selectivity and sensitivity. I had never used the stuff before, but I knew that a special kind of "woven" multi-strand wire worked best for radio coils operating at broadcast frequencies. Of course, I'm talking about litz (German for woven) wire that reduces something called the "skin effect." Because of the magnetic field that is generated by AC flowing in a conductor, electron flow is forced out to the "skin" or outermost part of the conductor. This is an undesirable feature of conductors carrying AC current but at 60 Hz it is hardly noticeable. The skin effect gets worse the higher in frequency you go and at radio frequencies, it is really bad causing high resistance in coils and ruining their 'Q' or "quality factor." Litz wire, because it is made of several wires woven together, noticeably increases a coil's 'Q' and allows it to tune much sharper. Litz wire also reduces a coil's resistive losses, thereby allowing the radio to pick up faint signals. I rewound both coils with litz wire and as expected, noticed a big improvement in both selectivity and sensitivity.

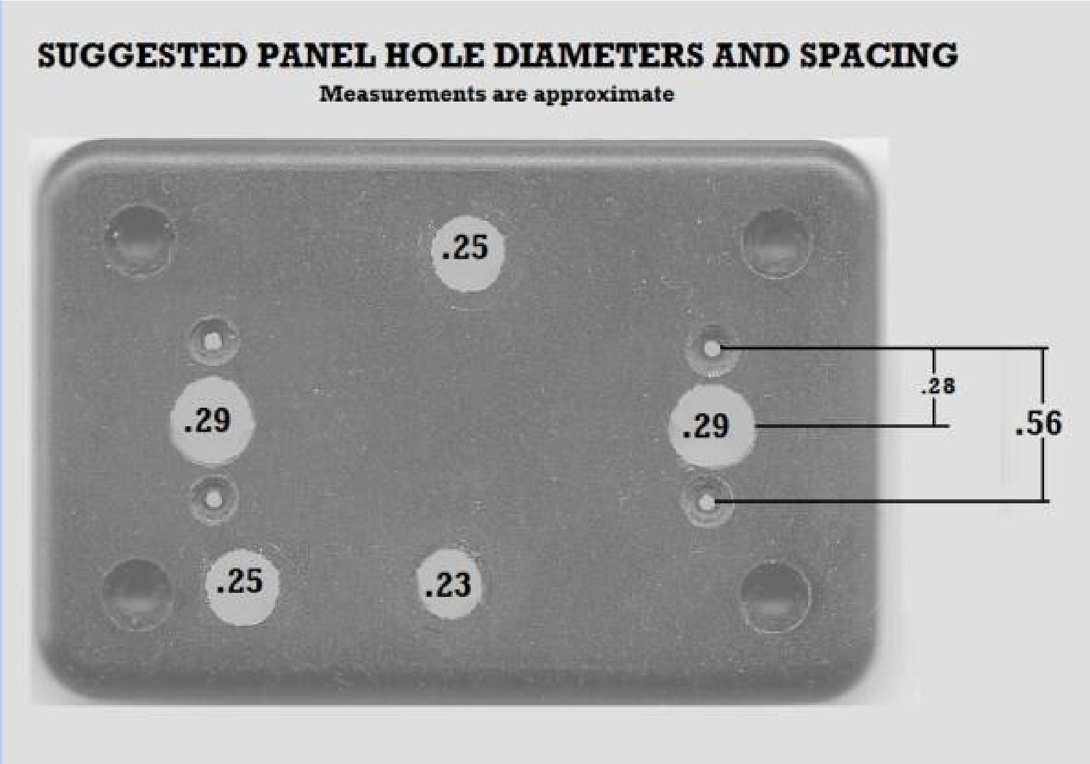
Next I experimented with detector diodes to see which kind gave the better sensitivity. Originally the radio used a BAT-46 Schottky diode for its detector. I even experimented with biasing the Schottky for additional sensitivity, but in the end, I replaced the Schottky detector with an ordinary 1N34A point contact diode. In my radio with its particular configuration, the old technology 1N34A diode gives superior performance.

I further experimented with with the the radio's selectivity by varying the coupling between the two toroid coils. With toroids, it is impossible to get a coupling lighter than a single turn unless you put a coil, a capacitor or a resistor in series with the coupling loop. To get the maximum selectivity out of one of these radios, it is necessary to have fairly light coupling between the antenna and the tuning toroid coils so at first I tried a resistor and it worked - sort of. When I put a little coil of Litz wire (wrapped around a bit of wooden match stick) in series with a single linking coil, I noticed a profound improvement to the overall selectivity of the set, but not much loss of sensitivity. A second coil was put in with twice as many turns on its matchstick and one or the other is selected by a little toggle switch. When this "larger" coil is selected, it very noticeably improves selectivity over the smaller coil, but it does cut down a little on the radio's sensitivity.

The station (detector) tuning coil is tapped 30 turns from the top so that 2,000 ohm magnetic headphones can be used without loss of selectivity.

In my radio's present configuration, its selectivity now matches the Heathkit CR1, but although very good, it isn't quite as sensitive.

Suggest layout and building instructions.



All measurements are in inches.

Steps in building the radio

First, shop around and pick out a suitable chassis box to put the radio in. A small box such as shown above will accommodate the miniature tuning condensers and the jacks for the earphone and antenna/ground RCA jack, however the parts will be crowded as shown in the pictures. A larger box will make assembly and soldering somewhat easier. A plastic box will make drilling and mounting the components extremely easy. A small wooden box that could be lacquered and polished might be very handsome.

The two capacitor extension shafts should be filed down for an overall length of 0.4 inches with the mounting screw cut to 0.48 inches. You can leave them their original length, but the knobs won't be flush with the panel.

This radio uses two T80-15 toroid cores that are each wound with 7 feet of 40/46 litz wire. Three turns on each side form a coupling link between the toroids. The station tuner coil is tapped 30 turns from the top. At what will be the top of this coil and with an inch of wire sticking out, square knot tie the wire to the toroid (to hold it in place) and then begin winding the coil while counting each turn. At 30 turns, stop winding and create a tap. Tapping is accomplished by simply twisting the wire for about a half inch. Carefully start winding again and continue to wind until all the wire is used up (about 70 more turns). When finished winding, the twisted wire at the tap and the wires at the ends of the coils are heated with a soldering iron until the insulation melts and then "tin" the wires with hot solder.

Note that the diagram that accompanies the tuning condensers shows which of the long metal tabs are connected to the stator (ground) and the rotor sides of the units. These condensers have 4 trimmers built into them, but we will not use any trimmers so ignore (or cut off) their tabs.

With the photos and schematic as a guide, perform the following:

1) For the antenna tuning condenser, bend the rotor tabs over at a 90 degree angle and solder them together.
2) For the station tuning condenser, bend the rotor tabs over at a 90 degree angle and solder them together.
3) Extend the ground tabs (stators) of the two condensers until they touch and then solder them together. This is the ground bus.
4) Solder short pieces of bare wire from the outer shells of the RCA and phono jacks to this bus.
5) Trim the leads to fit and solder one side of the 24K resistor to this bus.
6) Place the other lead of the 24K resistor into the mounting hole of the ungrounded side of the phone jack.
7) Trim the leads of the detector diode to fit and place one lead in the same hole of the phone jack with the 24K resistor.

8) Solder the detector diode and 24K resistor leads from steps 6&7 to the phone jack.
9) Place the station tuning coil on top of the station tuning condenser and perform the following:
10) Solder the top of the station tuning coil to the station tuning condenser's rotor tabs.
11) Solder the bottom of the station tuning coil to the ground bus.
12) Place the antenna tuning coin on top of the antenna tuning condenser and perform the following:
13) Solder the top of the antenna coil to the ungrounded lug of the RCA jack.
14) Solder the bottom of the antenna coil to the rotors of the antenna tuning condenser.
15) Glue the two toroids to the tops of their tuning condensers as shown. Use a silicone rubber adhesive and allow it to set.
16) L1 With a 4 inch section of litz. wire, wind 6 turns on a wooden match stick and glue them down. Leave one end with a long pig-tail and the other end a little shorter. Trim off the excess wood.
17) L2 With a 4 inch section of litz. wire, wind 12 turns on a wooden match stick and glue them down. Leave one end with a long pig-tail and the other end a little shorter. Trim off the excess wood.
18) Solder the short end of L1 to the "wide" terminal of the switch. No stripping is necessary with litz wire.
19) Solder the short end of L2 to the "wide" terminal of the switch. No stripping is necessary with litz wire.
20) Thread the two L1 and L2 long wires through both toroids as shown and bring them out together to the center terminal of the switch. Twist them together and solder them on. Remove excess wire.
18) Solder the other side of the detector diode to the tap of the station tuning coil as shown.
19) Solder two 3-6 inch pigtail leads on to the RCA plug for the antenna (red) and ground (black) and solder alligator clips to their ends.
20) Connect the alligator clips to a long wire antenna and suitable ground, plug in the earphone and tune to a local station. Recheck wiring if you fail to detect a station.

Refer to the schematic diagram and the photos below to make sure you have wired everything correctly. Remember that a schematic diagram is not exactly as a radio is wired, but is electrically correct and actual wiring must make all the connections (and no others) as shown. As long as the leads are kept short and if all the connections are made properly and there are no shorts to other parts of the circuit, the radio will work It is up to you to figure out the best routing and lead lengths for all the connections shown in the schematic. Keep in mind that external connections such as to the earphone, the antenna and the ground go to the earphone jack and the antenna jack respectively. If you are not familiar with schematic diagrams and how to wire something up using such a diagram, this is an excellent project for you to start learning how this is done.

Finally, the RCA jack and the phono jack normally uses the outside shell connected to ground so that when they are bolted to a metal panel, they are at the right potential. If you are using an insulated panel to mount these jacks, it doesn't matter if the outside shell is grounded, but I recommended that you connect it this way. You may notice that the detector diode is shown in the schematic as "forward biased," however, it makes no difference (in this case only) which way you connect the diode.

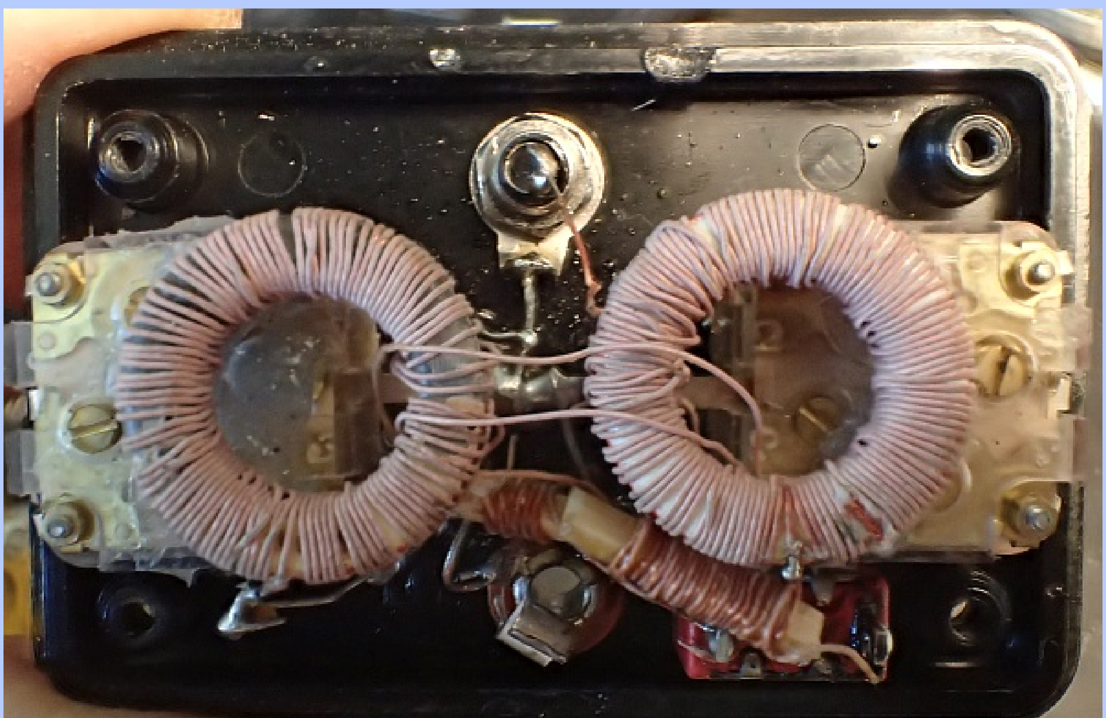
Tools you will need

1) A low wattage soldering iron. A temperature controlled soldering station is ideal, but an ordinary iron will work fine.
2) A very fine needle nose plier or (better yet) a fine hemostat.
3) A small wire cutter.
4) Drill, bits and countersinking tool for cutting holes in the panel.
5) Screwdrivers to fit the various screws.
6) Pliers or wrenches for tightening the jack's mounting nuts.

Do not over-tighten screws or nuts.

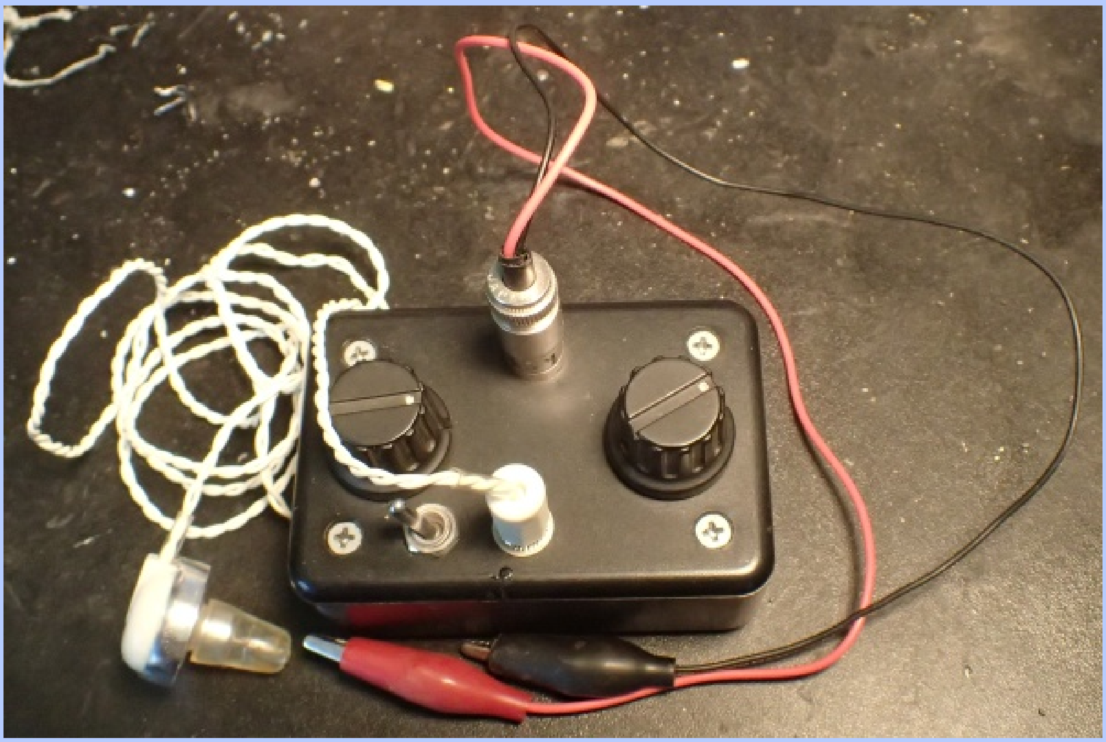
Photos of the completed project in its tiny box

Plastic lid with all components mounted. The toroids are mounted with a drop of RTV.
Silicone rubber mounts the toroids quite securely, but allows for future changes.
Miniature tuning condensers have dual sections, each 335 PF and are ganged for 670 PF.
The long ground tabs of the two condensers are soldered together and make a very convenient ground bus that the other components can attach to.
Also shown here are L1 and L2 which are turns of litz wire wrapped on match sticks.
This little radio will tune to the LF band below the broadcast band, but I doubt you will find anything down there to listen to.



Looking down with the phone jack at the center bottom and the RCA antenna jack on the top.
Notice a ground bus runs in the center connecting the two condensers and that the other components are soldered to it.

The front panel. Antenna tuning on the left, station tuning on the right.
The toggle switch controls wide or narrow selectivity tuning.



The completed project with a RCA plug attaching the antenna and ground.
I think you will agree that this is a very neat little package.
The tiny size belies its rather excellent performance.

Here's a picture of both my radio and the Heathkit CR1 showing their relative sizes
This is an old photo before the wide/narrow selectivity switch was installed.

The way this radio works is as basic as it is possible to get
and here's how it all works:

The setting:
Imagine that there is a radio station 10 miles away and that it that is broadcasting radio waves at 1,400 KHz. Imagine that our radio station is broadcasting hundreds of watts of energy into space and that if we could capture just a tiny amount of this energy, it would be possible to hear what was being broadcasted. Imagine that we have a crystal radio like the one above connected to a long wire antenna.

(1) The passing radio wave from our station induces a tiny high frequency voltage on our antenna wire. The antenna is connected to the antenna coil (coil on the left of the diagram) with its antenna tuning capacitor to the left and below it.
.

(2) When the antenna capacitor is tuned just right so that the inductance of the coil is matched by the capacitance of the tuning capacitor, a tiny current from the antenna flows in the antenna coil to produce an oscillating (or varying) magnetic field inside the toroid core on the left. By carefully adjusting the antenna tuning capacitor, this oscillating magnetic field will be right in tune with 1,400 KHz and 1,400 KHz only. This is important because it helps separate our 1,400 KHz signal from all the others on the AM band.
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(3) The oscillating magnetic field created by currents in the antenna coil causes a voltage to be developed in the turns of the link coil through the principle of mutual inductance. The oscillating voltage in the link creates a oscillating magnetic field in the right side core the core that has the station tuning coil wound on it. The link isolates the two circuits so that unwanted signals are not coupled between them.
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(4) The 1,400 KHz signal that has been coupled to the station tuning coil is contained in a "tank circuit" that is made up of the station tuning coil and the station tuning capacitor (shown to the coil's right).
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(5) By carefully adjusting the station tuning capacitor so that its capacitance exactly matches the coil's inductance, a so-called tank circuit is formed. This tank circuit "resonates" or "tunes in" the 1,400 KHz signal and that means that it further separates our 1,400 KHz signal from all the other nearby signals. We now have just the radio signal we want, but we need to do more because it is impossible for our ears to hear radio frequency signals.
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(6) To "detect" the presence of the radio frequency signal that is resonating in the tank circuit, the station tuning coil is wired to one side of the 1N34 detector diode.

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(7) The 1N34 diode chops off the negative part of the radio frequency wave. The detector needs to do that or the negative part of the wave would cancel out the positive part of the wave and nothing would be heard.

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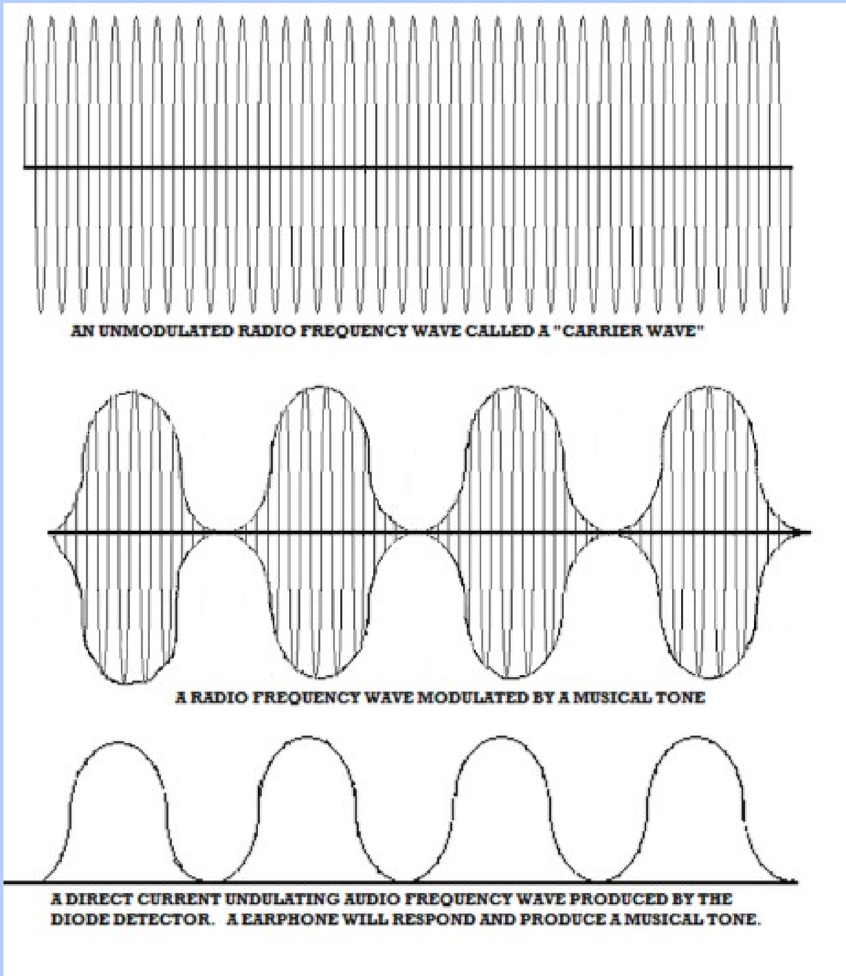
(8) When the diode detector chops off part of the radio frequency signal, direct current audio frequency undulations are all that are left over from the original radio wave. These direct current audio frequency undulations correspond to the sound being transmitted by the station and when the wires of a very sensitive earphone are connected to the detector, these undulations of direct current cause the mechanism inside the earphone to vibrate in step with the undulations and it is those vibrations that we hear as sound.

Here is a graphical representation of what's going on when a radio frequency signal is detected (turned into sound):



Graphs of the various waveforms seen at the tuner stage (top two) and at the detector stage. Unmodulated carrier waves are also called "continuous waves" and can't be heard by a crystal detector except as a kind of a very faint humming noise and a quiet spot on the tuning dial. AM radio stations try to avoid sending out unmodulated carrier waves (called "dead air") and so this waveform is rarely seen. More common is the waveform showing lower frequency sound waves superimposed on the carrier wave.

The thick black line is where the voltage is zero as a carrier wave crosses from positive to negative. As shown here, the negative going parts of the wave are stopped by the detector diode so that positive to zero to positive undulations remain. If

you reverse the diode, the direct current undulations will be negative to zero to negative, but the same musical tone will be heard in the earphone.

Crystal radios use only one half of a radio frequency's wave because full wave rectification is unnecessarily complicated and results in reducing the selectivity with little or no increase in sensitivity.

The importance of a good antenna and ground system

These radios are not connected to your house's AC power and they use no batteries. A crystal radio has no amplifying circuits and yet they output sound and sound is energy. Where do they get the energy to make sound? Do they somehow use mysterious and occult "free energy from space" or something goofy like that? The energy needed to run these radios doesn't cost you anything directly, but it isn't free or mysterious. The energy is from a tiny fraction left over from the hundreds of watts of radio frequency energy a station broadcasts out to space. The vast, vast majority of the energy a broadcast station radiates out of its antenna system is lost, but a tiny fraction of it may be picked up by an antenna at somebody's house.

Antennas for listening to AM stations can range from tiny "loop" antennas that are extremely inefficient, but good enough for amplified radios, all the way to elaborate "long wire" systems dozens and dozens of feet long and high up in the air. The general rule was discovered by Marconi over a hundred years ago that the longer and higher the antenna, the better it is at capturing some of that energy that is passing by. To capture enough passing energy so that it can be processed by the crystal radio's components and then come out as sound energy strong enough to vibrate the mechanism inside the earphone, the antenna needs to be as long and as high as is practical. Practical is what you have room for and how high you can safely go. Practical antennas can be strung between poles located at the ends of a roof or from the house out to a distant tree or pole. It is true that antennas longer than 60-100 feet and higher than 25 feet do capture more energy, but things soon get very difficult and for very little extra gain at distances and heights beyond what is practical.

In addition to a really good long wire antenna (as long as is practical as mentioned), this radio must have a good ground. Right now, I am using my house's wiring as a ground and it seems to work well. Water pipes, when available to connect to, are supposed to work even better. When using house wiring, it would be a deadly mistake to connect to anything but the AC ground, so be careful.

Tuning this radio for maximum sensitivity and selectivity

The trick to tuning this radio is to first locate a strong local station of known frequency and tune it in with both the antenna tuner and the station tuning controls. Both controls should be used to peak the signal for maximum loudness. Once you have an idea where on the dial your station is located, move both controls to about where you guess the weaker station you want to listen to might be. Once there, slowly and carefully adjust the station tuning until you hear something and then peak it up with the antenna tuning control. You may have to go back and forth a few times to get maximum volume with minimum interference from nearby and stronger stations.

The best time of the day to have fun with these kinds of radios

During the daytime and during the summer months, about all that can be received with a little set like this, at least around here, is the trash in English that the local broadcasters pander to and a couple of Mexican language and music stations, but in the evening, electrified layers way up high in the outer fringes of the atmosphere allow radio waves to be bent back down to earth so that interesting stations worth listening to, but which are 200 to 300 (sometimes even more) miles away may be heard loudly and clearly. This long distance "refraction" or bending of the radio waves back to earth (a process called "skip") makes it possible to hear these distant stations, but it isn't like listening to the station next door. This "skipping" of radio waves off electrically charged layers in the upper atmosphere makes these signals subject to all kinds of things including interference from even more distant stations, fading in and out, some strange sounding distortions and sometimes there is even an echo effect. These so-called "propagation effects" can be annoying, but if you just wait a few seconds or minute or so, the signal generally returns.

I think that listening for yourself, to hear what Nature is doing to these signals way up in the sky, is part of what makes listening to the Broadcast Band at night so interesting. There is a certain randomness to this skip that is explained to some degree by solar astronomy and physics. Scientists and engineers all over the world

closely monitor our local star and measure it for electrical and magnetic activity. Reports and prediction tables are compiled by various scientific agencies and all this stuff is available on the Internet. When you can test these predictions for yourself by listening for "skip," you are participating in a scientific observation in your own little way.

Building and operating a crystal radio gives insights into science and technology

Listening to far distant stations with a crystal radio like this one shows you how ships like the Titanic could communicate with other ships and to shore stations hundreds of miles away with nothing more than crystal radio receivers. Speaking of the Titanic, two thirds of all the people on her died and only about 700 were rescued, but without early radios, very much like this crystal set, everybody would have died. In the 100 years since the Titanic disaster, just imagine how radio has connected ships, airplanes, space missions and your cellphone with the rest of the world.

If you make one of these radios and actually put it to use, you will see how, with a good antenna and good sharp tuning circuits, individual radio signals can be picked out from the mass of signals out there and a station you might want to listen to can be heard from a long way off under the right conditions. For me, this is a very wonderful thing, especially when I consider that these radios do not amplify their signals, but use the tiny amounts of electrical energy that is picked up by the antenna to make sound. Such is the extreme sensitivity of human hearing and the amazing efficiency of the circuits, the detector crystal and the earphone, that microwatts of power, originally coming from a station hundreds of miles away and landing on my antenna wire, can be heard clearly.

How far we have come

When you think about it, it seems that such basic radio technology represented by this little crystal radio is quite old, but in fact, the first Fleming Valve and crystal radios were invented just a little over 100 years ago. When my mother was a girl, people were building crystal sets so that they could listen to the wonderful new radio broadcasts from the big cities. In a relatively short span of time, the time since my grand parents were young in the 1890s to my parent's time, to this very moment, consider just how far we have come with radio, television, GPS, cell phones, satellite broadcasting, wireless Internet, interplanetary missions to space and so much other allied radio technology.

A totally irrelevant comment

I know that the following is irrelevant to this article, but I'd just like to say that compared to the one tube (valve) Armstrong regenerative radio I built in 1958 while in the 8th grade (and without any adult help or supervision and the story of which is found elsewhere on my website), both the Heathkit and this little crystal radio really suck. It is no wonder that the crystal radio was quickly superseded by valve radios (starting about 1919 and using Armstrong's designs) even though the early vacuum tubes (valves) were extremely expensive, ate up expensive batteries and quickly burned out. Yes, even by 1920 the crystal radio was technically obsolete and their owners started to become just a tiny fraction of the listening public that they are today. Nevertheless, crystal radios did not completely disappear. They have remained popular all these years and years and years because these little radios are easy and cheap to build and they have provided endless hours of fun and precious education to uncounted numbers of people over the decades.

Why you might want to have second thoughts about building this radio

(These are my personal opinions that you are not obliged to agree with and you may skip down if you wish)

There is something that should be considered when thinking about having your young people build any kind of AM radio and what I'm referring to is the unpleasant realization that, in many places in the U.S., there is absolutely nothing on AM radio that is (in my opinion) good for young, developing minds to listen to. Many local broadcasters pander to the most disgusting right-wing propaganda and Fundamentalist religious crap. Anyway, it is my opinion that persons wishing to direct young people into building a simple AM radio should carefully monitor their local AM broadcasting for the kind of trash I'm taking about. If the local airwaves are full of this trash, they must ask themselves: would building this kind of a project likely help or harm their young people? I think building an AM radio can have the potential to do more harm than good if your area is dominated (as mine is) with this sort of trash broadcasting. Now, on the other hand, if you actually WANT your kids to be exposed to religious or political propaganda before before their minds are sufficiently developed to resist brainwashing, then ignore this warning.

Of course, this applies to adults wishing to build one of these radios too. Is it really worth the expense and especially the effort to build a crystal radio when there is nothing to listen to? I did it strictly for the technical

challenge, but certainly not to listen to local entertainment.

All this aside, if you decide build this radio or (better yet) my Armstrong "crystal" radio, I think you will have a lot of fun and will learn a lot. Just remember that for about the same money you can get a MP3 player with an FM radio and 8 gigs of memory. While the MP3 player is a better deal, listening to it won't teach you anything about electronics. However, the horrible trash that's on AM radio has a well deserved reputation for making its listeners stupid and crass while listening to classical music through your MP3 player just might make you smarter and highly cultured, but it's your choice.

Other considerations

Finally, there are some serious downsides to building this radio you should be aware of. One downside is the extreme tediousness of winding the toroid coils. Let's face it, few of us have toroid winding machines and putting 100 turns (about 7 feet of wire) on one of these cores is time consuming and boring with many a tangled wire. Mounting the tiny components wasn't all that difficult because the plastic box lid was very easy to drill, but it was fine work and time consuming. The most serious downside is the very fine and very careful soldering that must be done to connect up all the very tiny parts. If I would have chosen a larger box to put everything in, the soldering wouldn't have have required so much patience and expertise, but it would still be, in my opinion, beyond the skill of most middle school (and younger) kids to do except under the most close and individual supervision especially when you consider that the young person would be handling a hot soldering iron that could burn him/her badly if mishandled.

A final word

I have to admit that with the exception of the Heathkit CR1 radio, this is the best crystal radio I have ever made or used and I'd say the project was a success. I'm sure that people will tell me that there are some ultra high performance crystal radios out there that have very sophisticated low loss coils, high quality tuning capacitors and superior detectors with that could outperform this and the CR1, but I have no desire to go to the trouble to try to build them.

By the way, if you build a crystal radio based on what has been presented here, please drop me a line and describe it to me and, if you can, attach some pictures. I'd sure appreciate it if you would tell me how much you like the radio and how it performs for you. You can write me directly at my geojohn.org mail address. Be sure to look over my story of the Armstrong "Crystal" Radio before you decide to build this or any crystal radio.
Good luck.

The End

Having arrived this far, obviously you have a superior attention span and reading ability that far exceeds that of the majority of web users. I highly value the opinion of people such as yourself, so I ask you to briefly tell me:

Did you enjoy this article or were you disappointed?

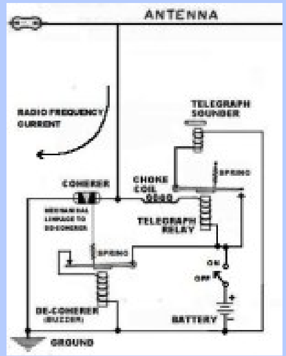
Please visit my guest book and tell me before you leave my website.

Or you can **contact me by E-mail** directly if you have any questions or comments.

If you liked this article, perhaps you would like to read about the radio my radio is based on.

The high performance Heathkit CR1 crystal radio

For more background on how early radio got started and evolved, perhaps you would like to read my essay on



[The Coherer and other Detectors used in early radio](#)

or perhaps you would like to read the article on

[The Armstrong regenerative radio I built in 1958](#)
And my first introduction to the wonders of vacuum tube technology.

Over 50 years later, I built a very similar radio using very cheap and easily available components.

[An Armstrong "Crystal" Radio](#)
Amazing performance from a radio that is easier and cheaper to build than almost any crystal radio.
If you want to build a simple radio yourself, this is the one I suggest.
from "The Old Geezer Electrician"

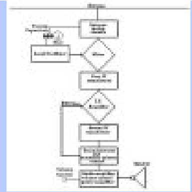
Here is a much better looking version of the same radio

[The Geezerola Senior regenerative radio](#)

You might like to read the story of my Armstrong regenerative radio that tunes shortwave and uses an FET for the detector,

[My Regenerative Shortwave Radio.](#)

I have written a little essay you might like that explains some of the principles behind



How The Armstrong Superheterodyne Radio Works

If you have an antique AM radio and you need something decent to listen to, perhaps you should buy or build your own

Low Power AM transmitter

or you can

Select another really entertaining radio article

or, as a last resort, you can

Return to my Home Page and look for something else

Radio Frequency Experiment by BH1RBG

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RF Homebrew Instrument >

Sawtooth: Ramp signal source

@2013/10/6

Ramp source and control knobs

Alan's lab present a good discrete Discrete Sawtooth Oscillators, after carefully study Alan's circuits, i change a little bit, get more suitable to use as oscillator for a fully functional ramp signal source.

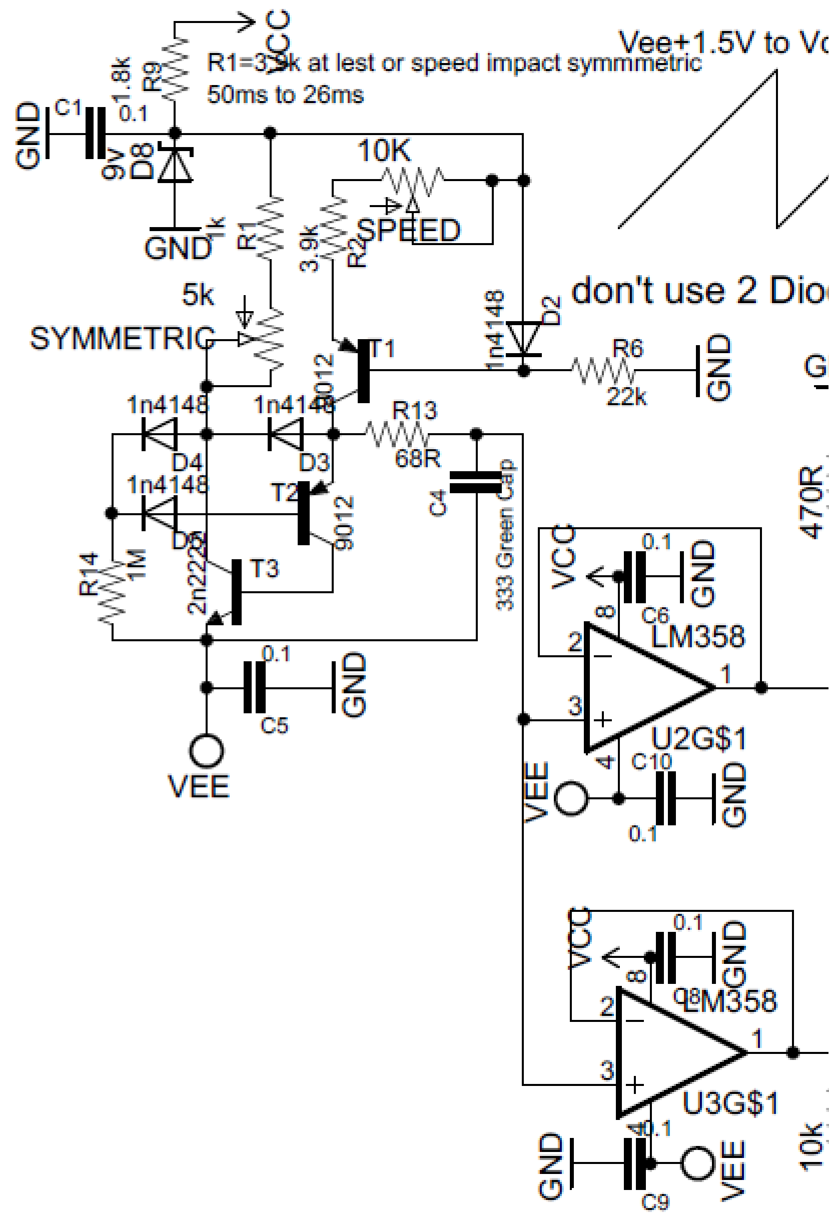
Compare to opamp sawtooth generator, this one has a wide sweep range:Vee-1.5 to Vcc-1.5. this make it no need to amplify it to full rail sweep. The 555 sawthooth generator sweep from 1/3 VCC to 2/3 VCC. The negative output for X axis is really good feature, which enable the DC couple to oscilloscope, eliminate AC couple distortion(AC couple use a coax, lack of compensation, coax capacitance leading to a bad sawtooth).

sawtooth generator include T1 T2 T3.

> *1.C4 must be a low leak capacitor, the green capacitor works very well.*
> *2. The SYMMETRIC pot actually is not very useful actually, if R1+ SYMMETRIC > 2k the output get severely distortion. to make it fully symmetric, use a adjustable negative rail supply.*
> *3.SPEED control work fine, but don't try to get it too fast, or the output peak will impacted by the speed. suggest 3.9k at least under +- 9V supply.*
> *4.D2,T1 is a constant current source. but it is not a normal type constant source, if you use 2 1n4148, the current flow through T1 will be always constant leading to stop oscillating. sawtooth oscillation utilize*

- Fuse based dead bug
- RF Calculators
  - Heterodyne tracking calculator
- RF Experiment
  - AMP: Simple RF Amplifer
  - Antenna: JFET active attenna
  - Audio: 2 stages Transformer Audio PA
  - Audio: Discrete Power Amplifer
  - Audio: low distortion wein bridge
  - Audio: Pre-amplifer 2011
  - Audio: Push Pull PA
  - Audio: Simple power amplifier
  - Audio: wein sine bridge
  - Bias: favorite BJT/JFET bias guide
  - CXO: CXO/overtone for TX
  - CXO: Low distortion oscillator
  - CXO: Tune 5th Butler Overtone VHF Oscillator
  - Fail: CB Negistor-not work
  - IF: BJT 2 Stage with AGC
  - LiPo: Simple charger
  - Miller negative resistance Oscillator
  - Mixer: JFET active mixer
  - Oscillator amplitude stabilization
  - Ramp: linearity ramp genarator
  - Ramp: Versatile ramp generator
  - SA: What is SA (SA demo prj)
  - Supply: dual Li-Po 7.2V-8.2V
  - Sweep: Build new topology signal source
  - Sweep: simple Hartley Sweeper
  - VCO: Franklin 80Mhz-180Mhz
  - VCO: AM Hartley LO
  - VCO: CB colpitts 270Mhz-500Mhz
  - VCO: Improved Series E VCO
  - VCO: linearity factor
  - VCO: Negative resistance VCO
  - VCO: Negative VCO Linearity
  - VCO: Seiler 80Mhz-300Mhz
  - VCO: Ultra Negtive 100kHz-100Mhz
  - VCO: Vackar 30Mhz-240Mhz
  - VFO: ultra-audion LF to VHF
  - VFO: AM band Oscillator
  - VFO: hybrid feedback oscillator
  - VFO: Several Dipper Ocillators
  - VFO:New topology of Series-E oscillator
- RF Ham Radio
  - 10M:28.6Mhz FM transmiter
  - 27Mhz: AM RX/TX Experiment
  - AM: AM band transmiter by Techlib
  - Antenna: Your first Antenna

such a character: current source is not always provide current to C4. if you have 2 1n4148, the T2,T3 might always keep saturation make it stop oscillating.



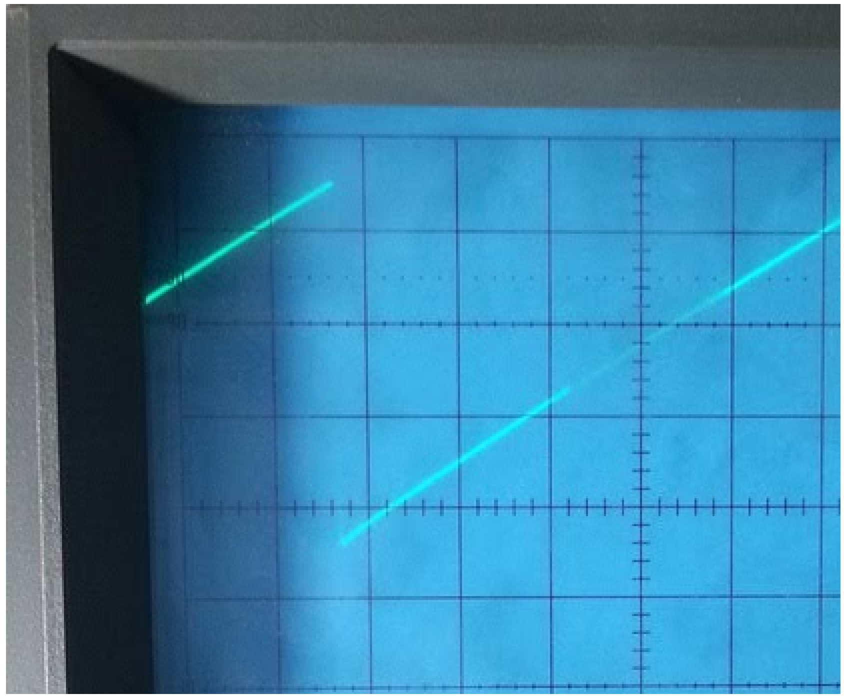
C-adj enable sweep center perfect located in th

Contact me

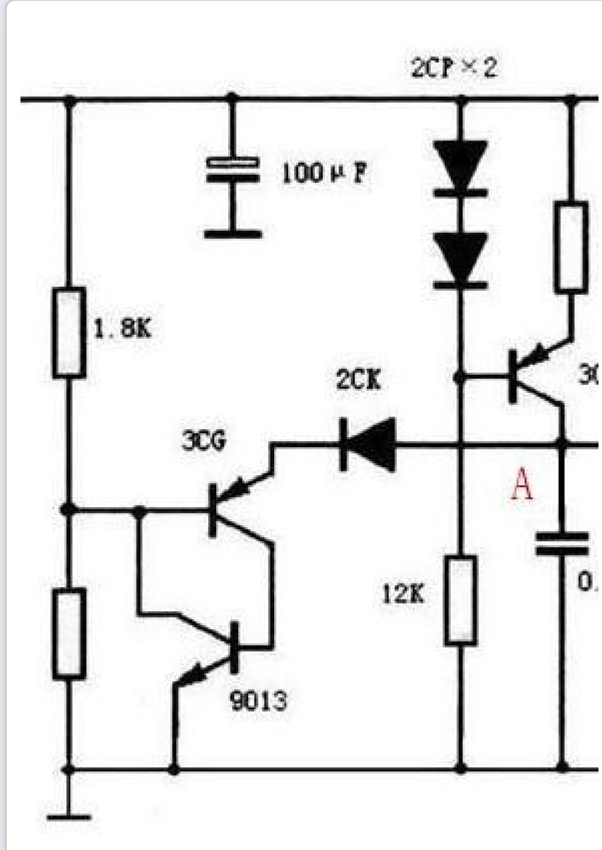
heyongli@gmail.com

G+

in general speaking, this circuit works very well at a 'special' quiescent work point. see the picture , it's good enough.



change T2,T3 to a configurable Unijunction Transistor might help a lot:



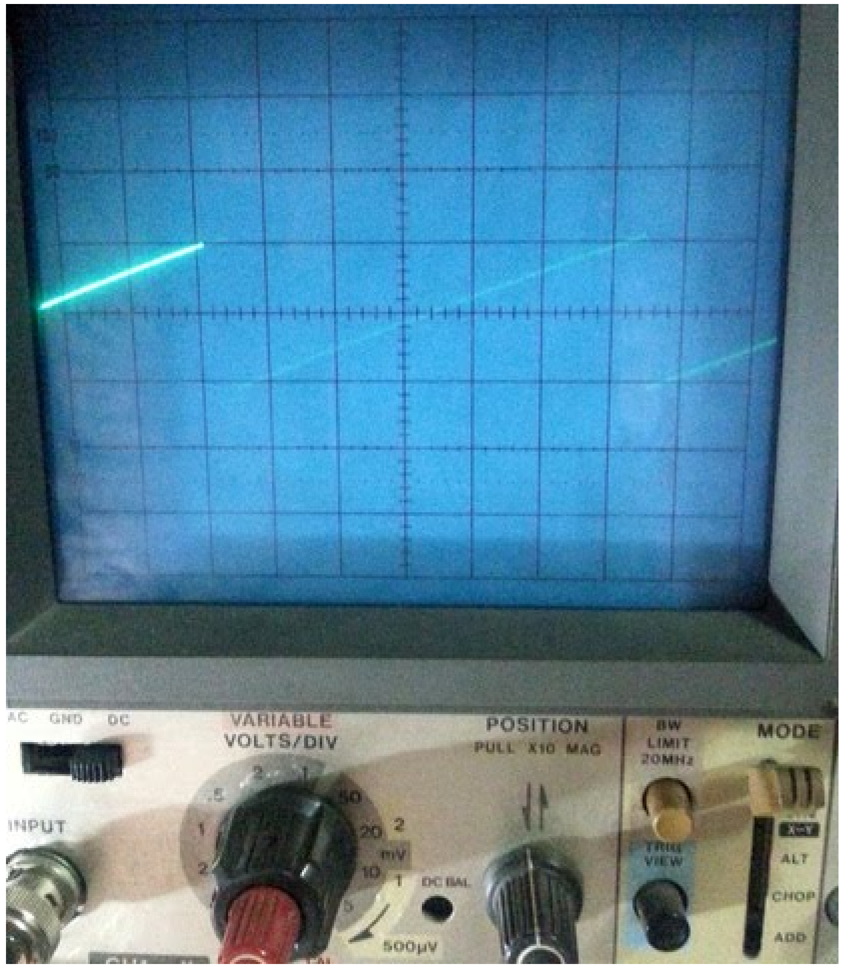
Now come to signal process part. U2, the LM358 work as a buffer, then a divider to given a +- 5V output for 1V/div of oscilloscope. U3 make a span control buffer, nothing special.

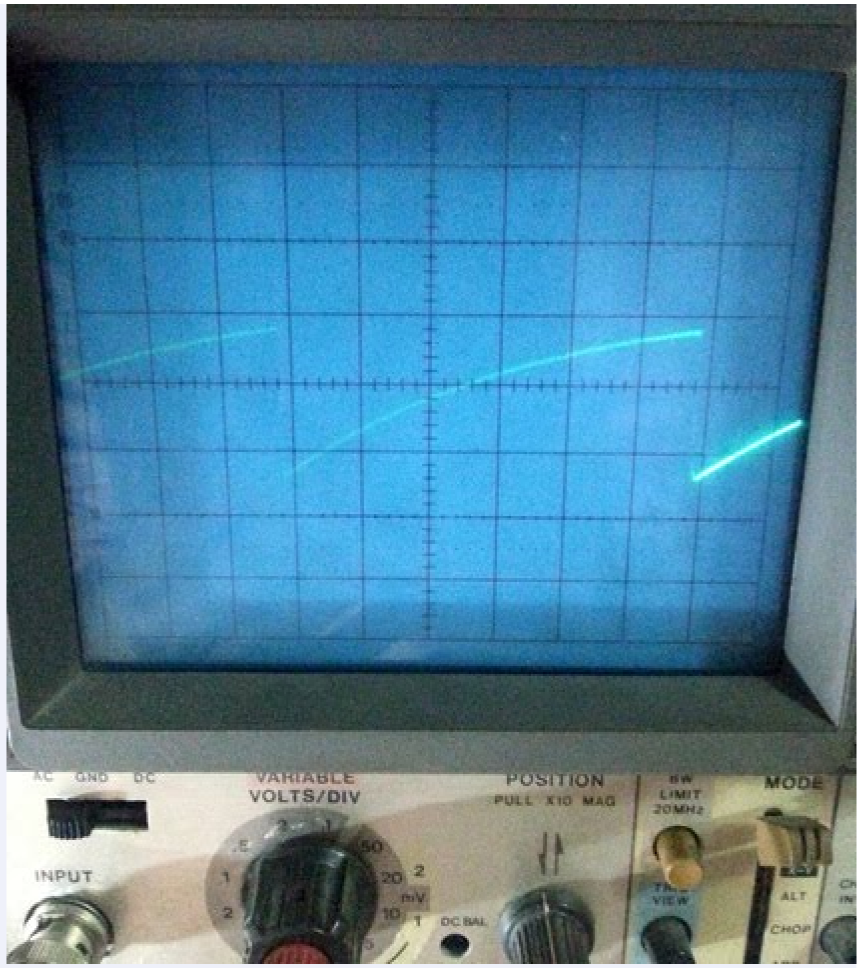
U1 is the centering control. to get better precise control, use a buffer for centring pot, but for fine tune, there is no buffer. U1 have another task: adding +9V to the sawtooth wave, convert it from (-8V +8v) to (0-16V).

wired thing happen while positive rail go up above 15V, the lm358 seem's introduce high frequency spur oscillating, add C5, C14 could filter it out.

following photo show the effect of AC coupled and DC couple:

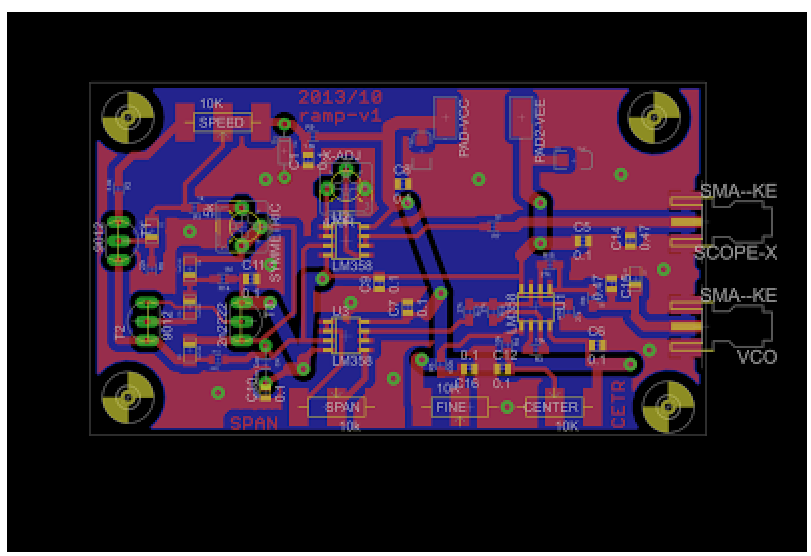
right photo is AC coupled to oscilloscope X, distortion obviously,   left photo DC couple to oscilloscope, dam good.


AC GND DC
VARIABLE
VOLTS/DIV
INPUT
mV
500μV
DC BAL
POSITION
PULL X10 MAG
BW
LIMIT
20MHz
TRIG
VIEW
MODE
X-Y
ALT
CHOP
ADD



PCB:
download: https://code.google.com/p/digital-toy/source/checkout

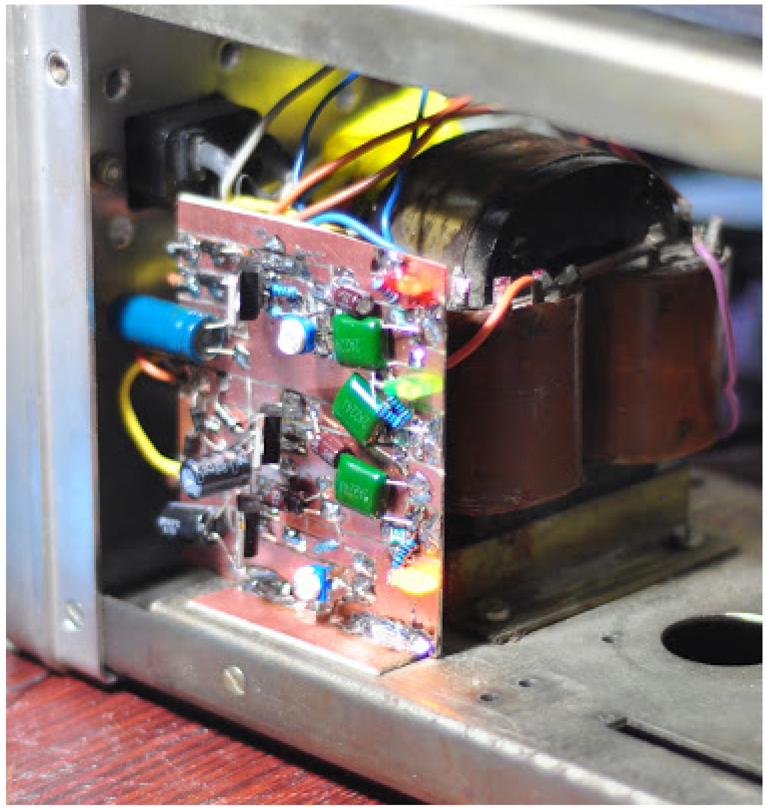
(Click image for large view)

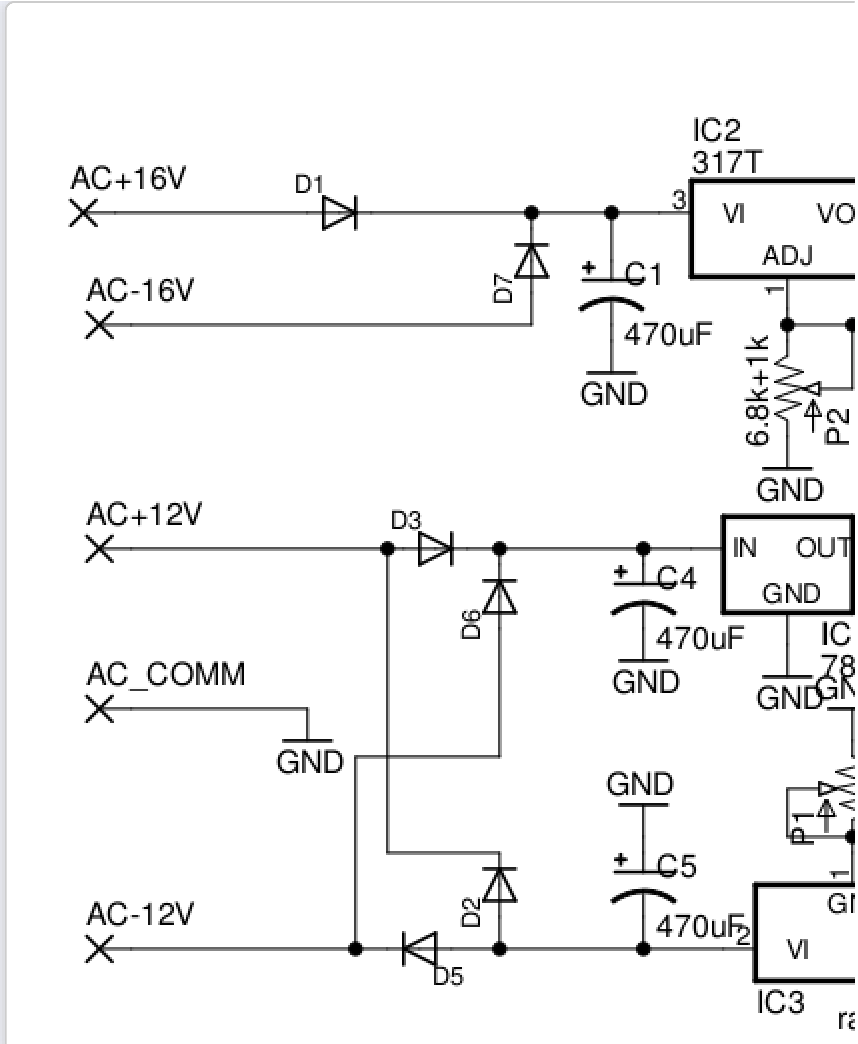


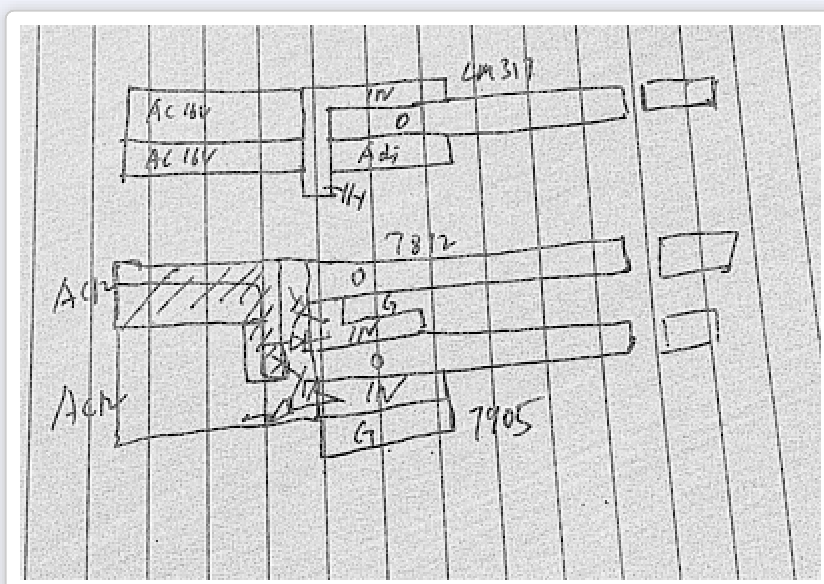
More @2013/9/10
add an offset resistor to the centre, now output from 1V to 16.5V. most of varactors linearity is bad at 0-0.5V.

Power supply Board and Case /Panel

Most of control function is in the ramp board, i finished it. so it's time to got a case put all of them in it and design a panel. i utilized a box of a old bench power, the extra award, a powerful AC transformer.

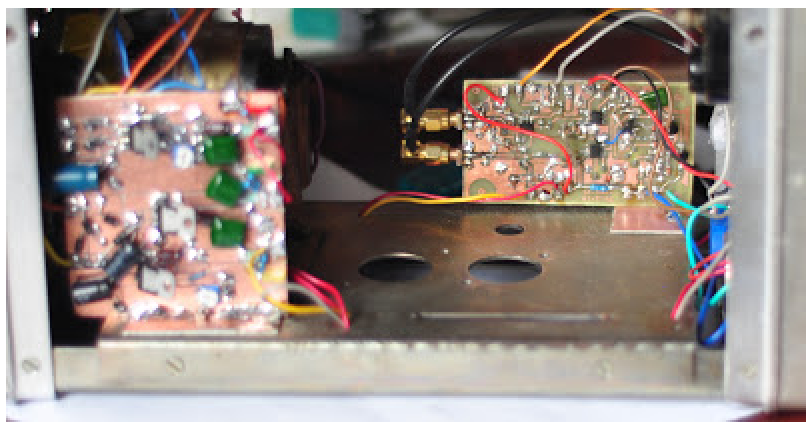


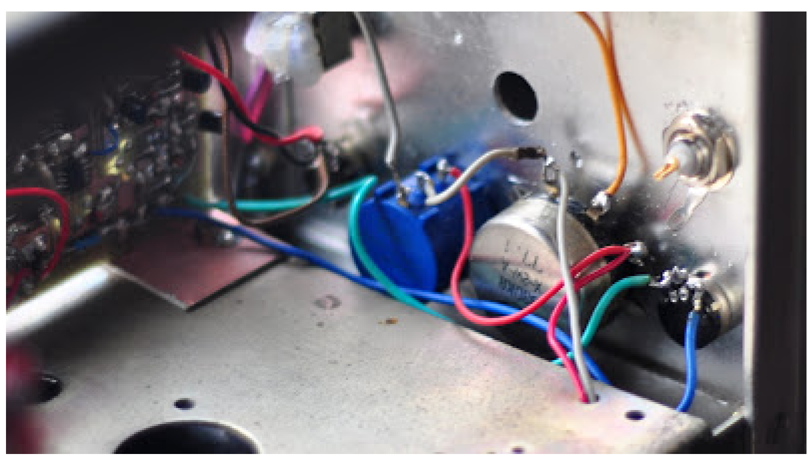




let's us look the great part, pictures of the real HW:


V-A





Why i need another cases for this

this case is not suitable for sweeper, it's internal space is relatively small, it's a cube, but we prefer it's be a flat cube, not so high. and all my other instrument is another shape, i.e, this one: **Couter: EP frequncy counter**. I finally get a similar, and even better cases for hold sweeper signal source and even could integrated the Power Meter.

Comments

You do not have permission to add comments.

Don't buy a radio; Build one!

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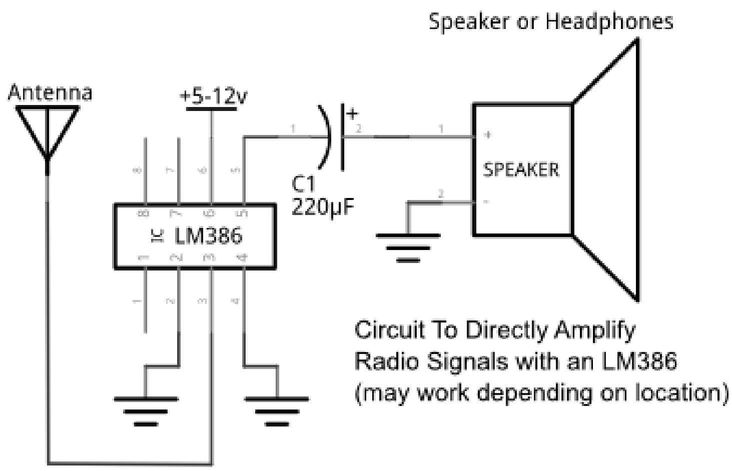
An LM386 Powered Crystal Radio in an Altoids Smalls Tin

Last year I was designing an Arduino powered doorbell for my new home, and I reached for the trusty LM386 to build the audio amplification stage. But, at my new QTH (a high elevation in a major city with line of site radio towers in the distance) the LM386 was not only amplifying the doorbell tones, it was also pulling in a nearby AM radio station! Although this was a major annoyance while designing the doorbell, I wanted to revisit the LM386 in the future as a basic radio receiver.

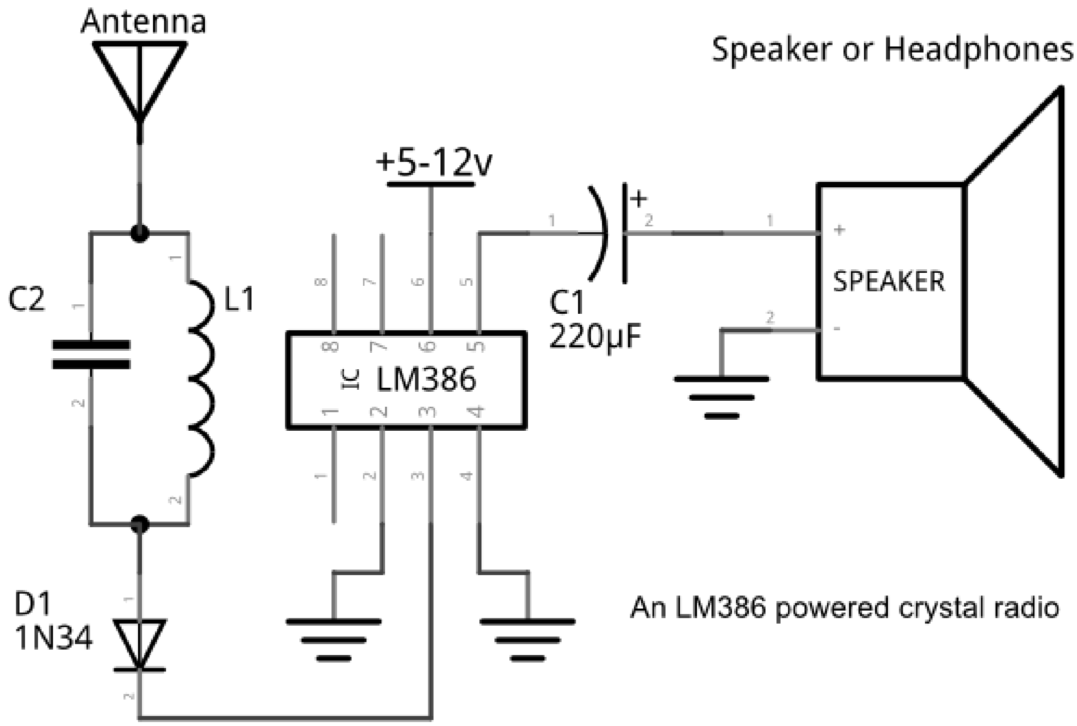
If you live in a location like me, then the following basic circuit may pick up the strongest local radio station, or you may hear a 60Hz buzz from your power lines, or you may hear nothing at all. *Try it at night for the best results.*



But, we can improve upon this basic circuit by adding just a few more parts, and gain better selectivity and sensitivity.

You may have heard of a crystal radio (or a *crystal set),* which is a simple circuit that uses a diode as an RF detector and a tuned LC (inductor / capacitor) circuit to receive radio. It's about as bare bones as it gets for a radio receiver, and if you have a crystal earpiece, you don't even need a battery to power it. It just pulls the radio waves out of the air and you can listen to them!

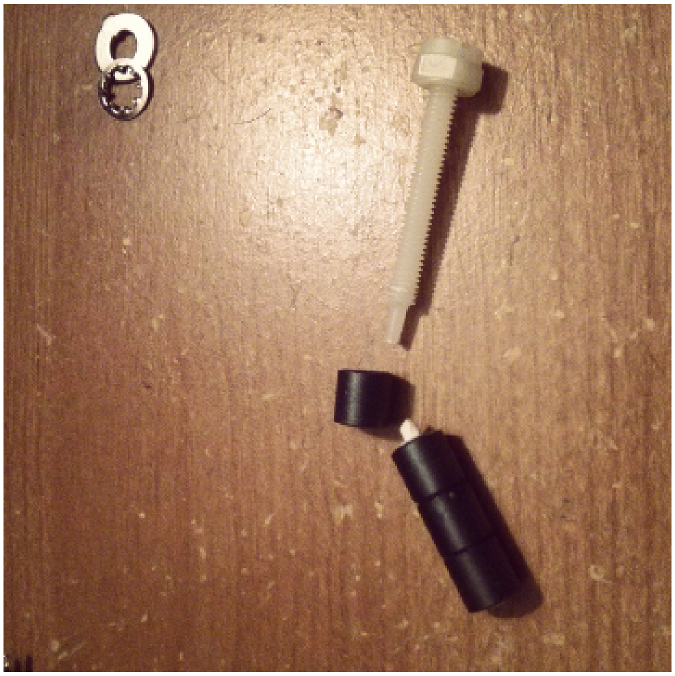
Well, I don't have a crystal earpiece, but I do have plenty of LM386 amplifiers and batteries, and from my doorbell experience, I already knew that the LM386 will amplify radio waves. So, I combined a basic crystal radio with an LM386 to create this basic AM radio:



You may be wondering where the "crystal" is in this crystal radio. It's in the diode that we are using to detect our RF signal. Specifically, this circuit requires a germanium diode as the RF detector -- at least you will have the most success with a germanium diode. People typically prefer to use the 1N34 diode for this application, but I didn't have any available so I used a generic germanium diode, and it worked well. You can find 1N34 diodes easily on Amazon, eBay, etc.

The circuit needs to be tuned to the correct range or you will hear nothing but static. I am using 35 turns of 24 gauge magnet wire around a ferrite rod for L1 and 1410 pF for C2 (use three 470 pF capacitors in parallel); but you will likely need to play with different values for your location. I took the radio with me on vacation, excited to show a friend my latest build, and it didn't work at all. I came back home and it worked great. So, optimizing for your location does matter.

You can tune the radio by adding or reducing either the L or C values (increasing or decreasing the inductance or capacitance of the tank circuit). I didn't have much luck tuning the capacitance with a few different variable capacitors, but tuning the inductance worked very well. To make my variable inductor, I took the 35 turns of magnet wire (mentioned above) and wrapped it on a thick paper form (a good use for junk mail!) that fit around the ferrite rod. To increase/decrease the inductance, move the ferrite rod in and out of the wire form.



I made a ferrite bar by gluing several ferrite cores to a plastic screw that could be used to tune the inductor (by moving the bar in and out of the wire turns).

Don't be stingy with the antenna! I was able to pick up the strongest AM station in my area with just a foot of wire, but when I hooked it up to my outdoor long wire antenna, wow! I could hear strong and distinct signals while tuning.

So, how does it perform? Pretty well for something so simple! With the above circuit (on the breadboard) I was able to tune into 4 or 5 local AM radio stations. I was also able to pick up a local FM station by removing the LC circuit and replacing it with about eight turns of loosely wound 22 gauge magnet wire around a pencil. Technically speaking, you should only be able to detect AM stations with a crystal radio, but FM detection is possible via a principal called *slope detection*.

I was pleased enough with the performance, and soldered it up inside an Altoids Smalls case. Getting everything to fit in the Altoids Smalls tin was a challenge, but a fun one. I used a 6v type-N battery, which saved a lot of room in the case.

Here are some pictures of the completed radio:

Unfortunately, the Altoids tin reduced performance of the circuit. The additional grounding of the metal case creating parasitic capacitance appears to be the culprit. It still works, but I was able to pull in more signals on the breadboard. The next time I build a crystal radio, I'll probably use a plastic candy case instead of a metal tin. But, it does work and looks awesome in the Altoids Smalls tin.

Side note: The size of an Altoids Smalls tin has apparently changed since the candy was originally released. I saw several places on the net that said that an Altoids Smalls tin could fit a 9v battery. The tin I picked up had a slightly different case design, and it was just slightly too small to close with a 9v battery inside. Of course, a regular size Altoids tin still fits a 9v battery well.

Posted: Jun 09, 2014

Keyword tags: altoidscrystal radiolm386schematic

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Radio Lab Project: writing the group report

TECH1002 Studies in Media Technology
2011-2012

Introduction

- This presentation provides detail about the content and structure of the **radio lab group report**
- The group report is one of **three** parts of the radio lab assignment
- **For further details about the radio lab coursework read pages 12-14 of the module handbook**

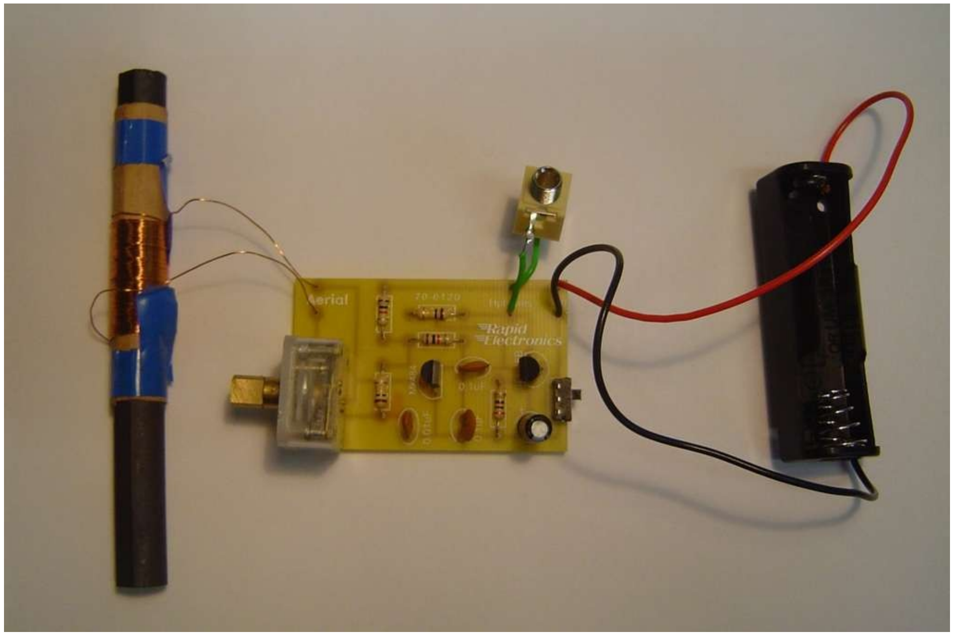
Assessment Criteria

- We will be looking for three main elements of achievement in the written report:
  - **Academic achievement – the ability to organize, structure and present a technical report**
  - **Use of research – the incorporation of background reading in to the report**
  - **Understanding and explanation of radio technology – the demonstration of a knowledge of the technical context of radio transmission and reception and audio amplification**

AM Radio Receiver and Audio Amplifier Project

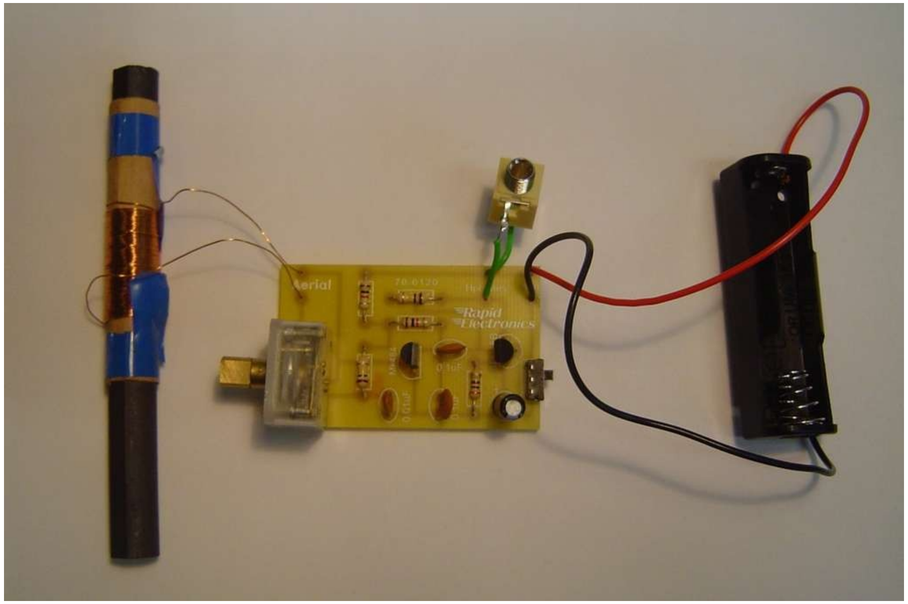
- The first main section of the report will present the making and testing of the AM radio receiver and audio amplifier
- The reception results should be recorded and explained
- If technical failure prevents the recording of actual results, then sample results will be provided later and can be used for the purpose of the theoretical explanation of typical results

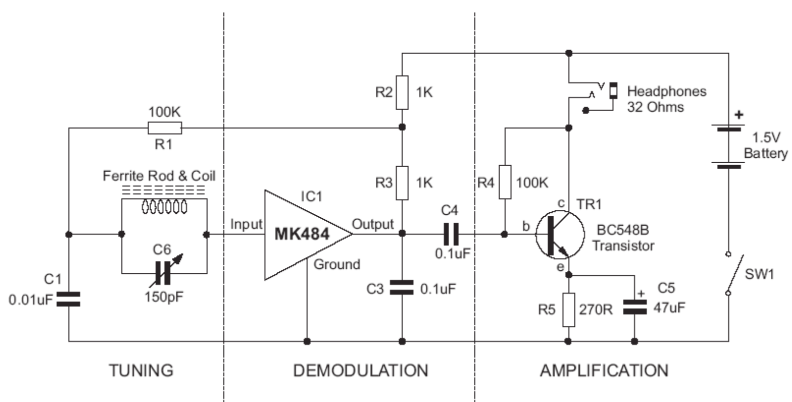
AM Radio Receiver



- It is important that the report explains to the reader how the AM receiver works and accounts for the results obtained.

AM Radio Receiver

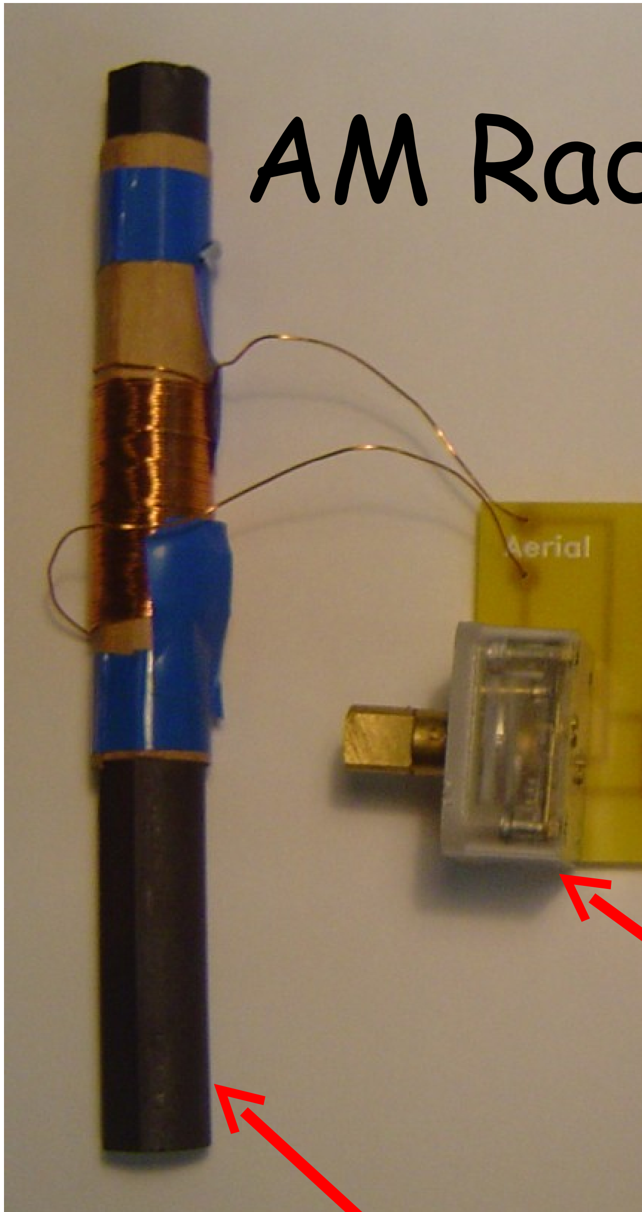




The diagram above shows the radio circuit used in the project. The ferrite rod and variable capacitor are to tune the circuit to the desired radio station. The MK484 demodulates the signal and the BC548 transistor amplifies the output to the headphones.

- The AM radio receiver circuit has three main sections:
- Tuning
- Demodulation
- Amplification

AM Radio Receiver: Tuning

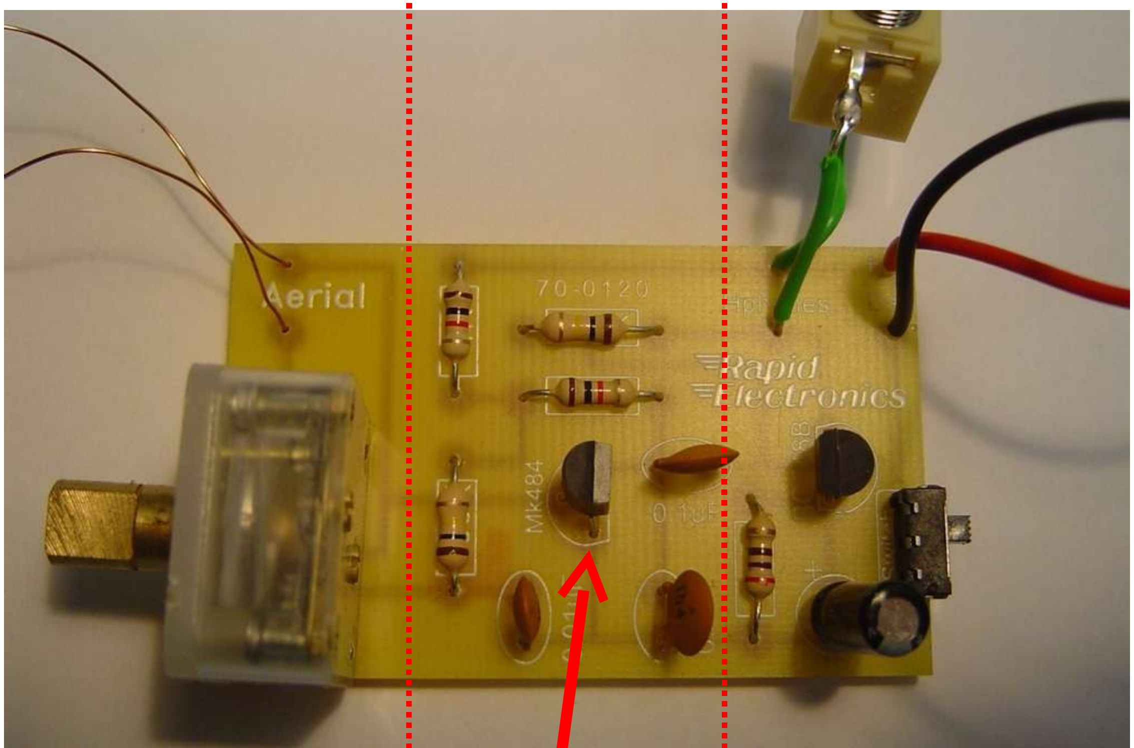


variable tuning capacitor (150pF)

coil aerial

- What are the key components of the tuning circuit?
- What is the function of the coil aerial?
- On what principle does a tuner work?
- What does the tuning circuit do to the tuned frequency?

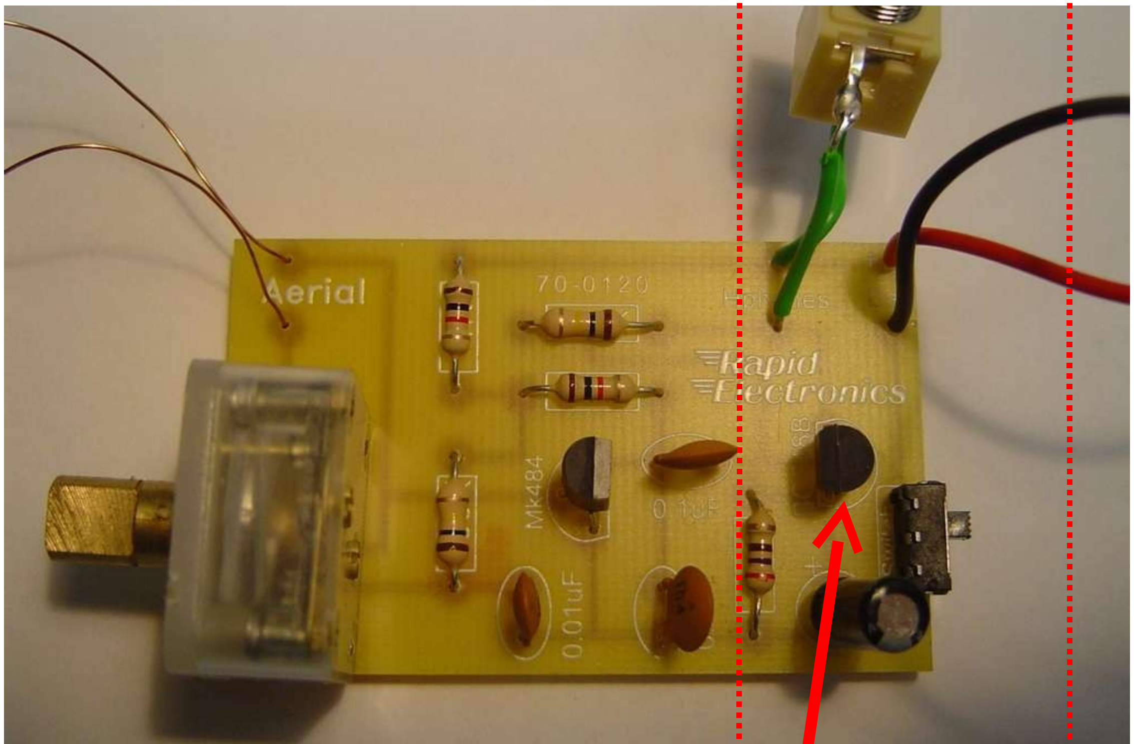
AM Radio Receiver: Demodulation



diode (MK484)

- What is the central component of the demodulation part of the circuit?
- How does this component demodulate the carrier wave?

AM Radio Receiver: Amplification



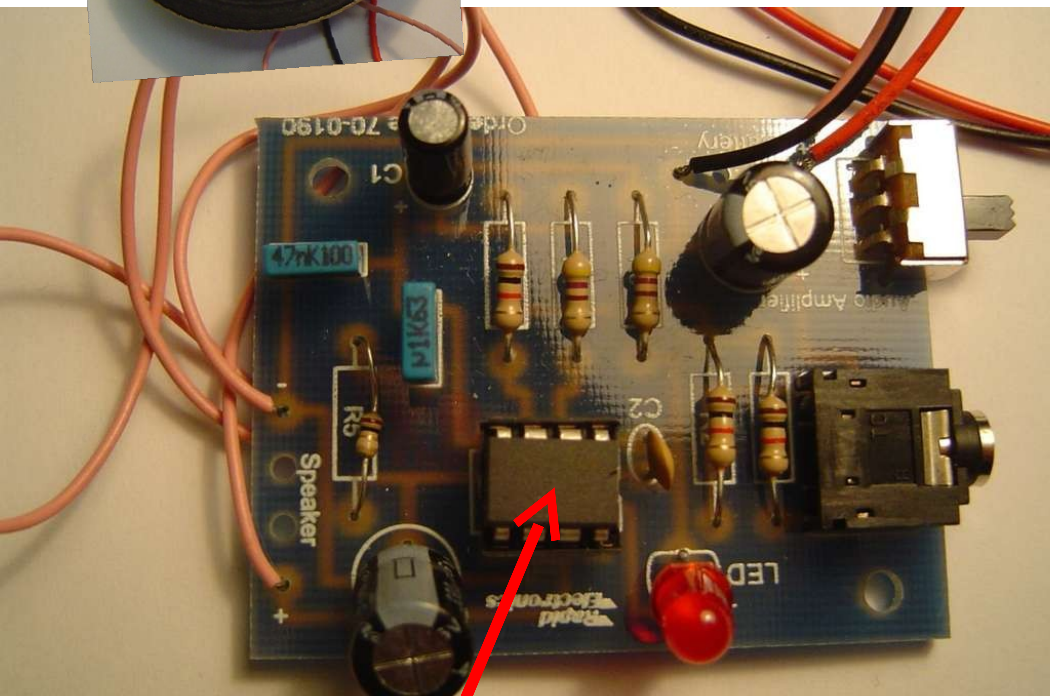
battery power

transistor (BC548B)

- What is the key component in the amplification part of the circuit?
- How does this component amplify the audio information signal and why does it need current such as from a battery?
- What is the level of amplification sufficient to do?

Audio Amplifier

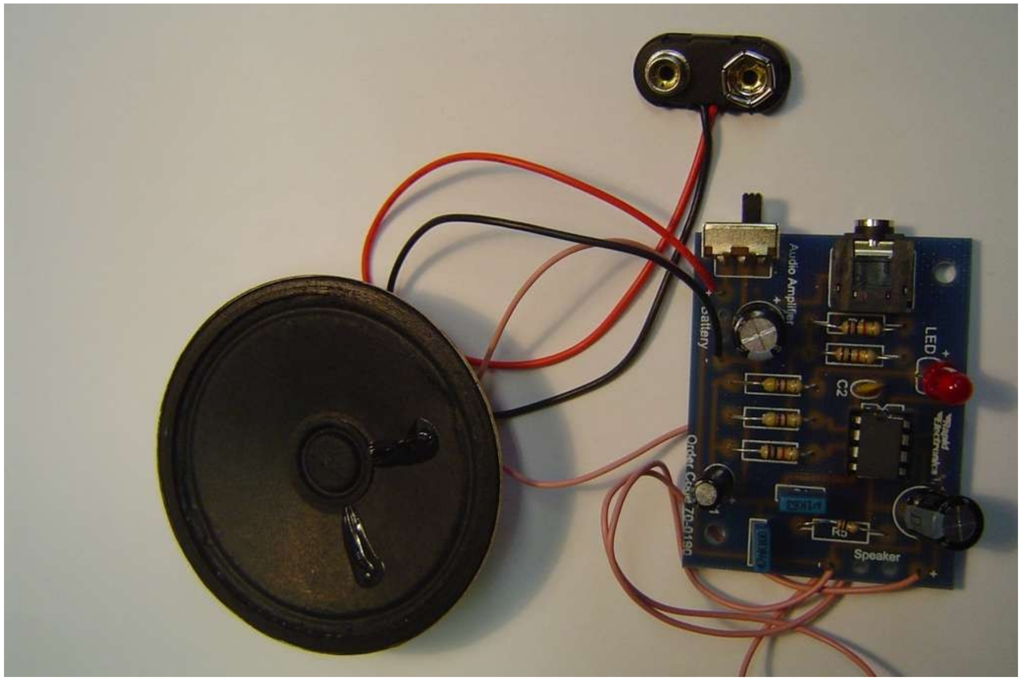
battery power



IC (Integrated Component)
TBA 820M

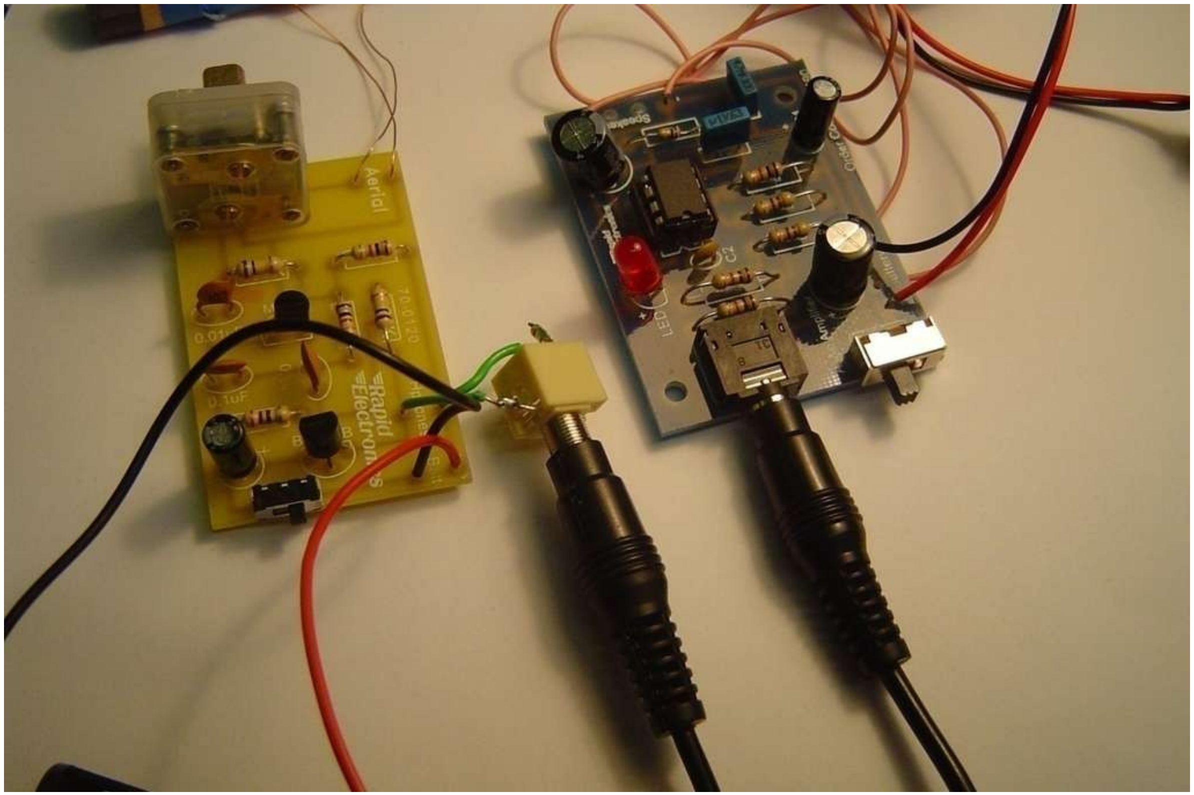
- How is sound represented in electronic sound equipment such as a radio?
- How does the speaker change the electrical audio signal into a sound wave that can be heard?
- What does the amplifier do to make the speaker work?
- What is the key component of the audio amplifier?
- What does this component do and why does it need electrical

Audio Amplifier



- It is important that the report explains how the amplifier works with the speaker.

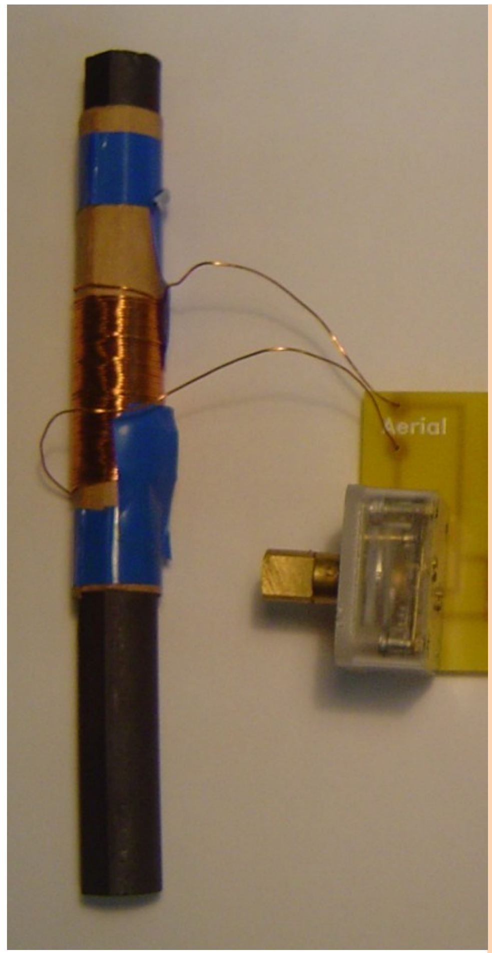
Reception Testing



The headphone socket of the radio receiver was connected to the audio jack socket of the amplifier via a 3.5mm cable to listen to the radio reception through a speaker.

- It is important that the report records the results of testing the reception and accounts for the results obtained.

Reception Testing



- What factors govern the quality of AM radio reception achieved by the radio receiver?
- What are the names and the frequencies of the radio stations that you were able to receive?
- Why were you able to receive these stations only?

Research

- Online information can give you the frequency of the carrier wave of the radio broadcast that your radio receives.

http://www.bbc.co.uk/asiannetwork/howtolisten/radio/

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About Sabras

Sabras Radio is regarded by many in the industry as the pioneer of Asian radio in the UK. The first broadcasts undertaken by the Sabras team were in 1976 with a local BBC radio station. Subsequently, and for many years, Sabras operated within the GWR Group, before becoming totally independent by winning its own licence in 1994 to broadcast on 1260AM. It enjoys the largest average listening hours of any commercial station in the UK and is listened to by an estimated 80% of its target audience in the region.

Both, national and local advertisers have been quick to seize the opportunities offered by this platform which connects the advertiser to one of the wealthiest sections of UK society today.

The continued success of Sabras Radio has allowed the station to undertake a wide range of activities including many significant outside broadcasts and other specialist RSL's (Restricted Service Licence) for important religious and cultural events such as Diwali, Ramadan and Vaisakhi.

Sabras Radio is also a shareholder in Now Digital (East Midland) Limited which owns two digital multiplexes in the East Midlands and on which in addition to simulcasting its AM programmes, it also broadcasts a unique mixture of formats on a new service – 'A Plus'. Web streaming across the internet has now made Sabras global and latest data shows that its streaming service has been listened to by people in no less than 76 countries.

VIEW PIX & LISTEN AGAIN JAY SEAN TALKS TO RAJ BADDHAN

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vodafone SABRAS BREKFAST COMPETITION

http://www.sabrasradio.com/sabras.php?p=about

FM list start	DAB list start	DAB list end	Unlisted
Reception advice	Station type colour codes	Programme formats	FM and AI

AM stations

Stations in bold should give strong reception day and night. Other stations will give weaker reception and may echo or be unlistenable at night. Stations in italic are not on air yet. Reception can vary within than one frequency of equal strength is given, try both. Some community stations and RSLs only cover part of a city. For details of stations only available at night, go to the Frequency order section.

kHz	Station	Broadcaster	Format	Coverage area
162	France Inter	France	French Mixed Format	France
183	Europe 1 (French)	Germany	French Talk	North, East and Central France
198	**Radio 4 Long Wave**	**BBC**	**Talk, News, Entertainment**	**England and Wales**
234	RTL Radio	Luxembourg	French Talk	North, East and Central France
252	**RTE Radio 1 (AM)**	**RTE**	**Talk, Soft, Easy, Irish & Country**	**Ireland, Scot, Wales, N, W & C Engl**
279	***To be decided***	***IOMBC***	***TBA***	***UK and Ireland***
693	**Radio 5 Live**	**BBC**	**News, Sport, Talk**	**Midlands**
837	**Asian Network**	**BBC**	**Asian**	**Leicestershire**
909	Radio 5 Live	BBC	News, Sport, Talk	Multiple transmitters
999	Classic Gold GEM	UBC/GCap	Oldies	South Nottinghamshire
1053	**Talk Sport**	**UTV**	**Sport, Talk**	**Midlands**
1107	Talk Sport	UTV	Sport, Talk	Lincs, Peterborough & Kings Lynn
1116	Radio Derby/ Asian Network	BBC	Mixed Format/ Asian	South Derbyshire and East Staffs
1215	Virgin Radio	SMG	Rock	Western Midlands Region
1233	Virgin Radio	SMG	Rock	Northamptonshire
1242	Virgin Radio	SMG	Rock	Lincs, Peterborough & Kings Lynn
1260	**Sabras Sound**	**Independent**	**Asian**	**Leicester area**
1287	**Radio Gwendolen**	**Hospital RSL**	**Mixed Music**	**Leicester**
1359	Classic Gold 1359	UBC/GCap	Oldies	Coventry and N Warwickshire

For transmitter details, go to the Frequency order or Station directory section.

AM reception in the Leicester area – one of the many supporting links that can be found online.

http://frequencyfinder.org.uk/tc/leicester.html#am_top

The local AM transmitter

- You should be able to find the location of the local AM transmitter and the power of the radio signal as part of your explanation of the results – **this is it – where is it?**

Other Sections of the Report

- **Introduction** – at the beginning of the report, tell the reader what the report is about, what it does, and how it is structured

- **Conclusion** – at the end of the report only, remind the reader what you have done in the report and a summary of the main points that can be drawn from the practical labs that you have undertaken. How do you evaluate what you have done? Evaluation involves forming a judgment about the value of something, an opinion based on evidence that you have presented in the report

Other Sections of the Report

- **Title Page** - the first page of the report should be a title page. This will contain the title of the assignment, the student numbers and names of your coursework group and your usual computer lab class (for example, A. CLAY THURSDAY 12-1).

- **Contents Page -** the next page will be a contents page referring to the page numbers where the separate sections start.

- **List of Figures Page** - after that will come a page called 'List of Figures', a contents page for all the diagrams and illustrations that appear in the report. All the diagrams and illustrations should be labelled (for example, Figure 1: AM transmission equipment) and if it is not your own diagram, you must reference its source.

Other Sections of the Report

- **Bibliography** – the report should end with a bibliography. Please consult the Appendix 1 in the module handbook for information about using bibliography and references. You should use the **Harvard** system of referencing
- **Appendix** – your radio lab log book sheets should be placed in the rear of the report in an appendix as a record of your attendance and engagement on the radio project **(Appendix 1)**

How to Make a Tesla Coil

Two Parts: Planning a Tesla Coil Making a Tesla Coil

Developed in 1891 by Nikola Tesla, the Tesla coil was created to perform experiments in creating high-voltage electrical discharges. It consists of a power supply, a capacitor and coil transformer set so that voltage peaks alternate between the two, and electrodes set so that sparks jump between them through the air. Used in applications from particle accelerators to televisions and toys, a Tesla coil can be made from electronics store equipment or from surplus materials. This article describes how to build a spark-gap Tesla coil, which is different from a solid-state Tesla coil and cannot play music. [1]

Part 1 Planning a Tesla Coil

1 **Consider the size, placement, and power requirements of the Tesla coil before you build it.** You can build as large a Tesla coil as your budget allows; however, the lightning-bolt-like sparks Tesla coils generate heat and expand the air around them (in essence, creating thunder). Their electric fields can also play havoc with electronic devices, so you'll probably want to build and run your Tesla coil in an out-of-the-way place, such as a garage or other workshop. You will also want to consider whether it makes more sense to build a Tesla coil from a kit, or gather materials from scratch. Both have advantages and disadvantages in the areas of cost, building time, resources for help, and reliability. [2]

- To figure how large a spark gap you can accommodate, or how much power you need to make it work, divide the length of the spark gap in inches by 1.7 and square it to determine the input power in watts. (Conversely, to find the spark gap length, multiply the square root of the power in watts by 1.7.) A Tesla coil that creates a spark gap of 60 inches (150 cm) (1.5 meters) would require 1,246 watts. (A Tesla coil using a 1-kilowatt power source would generate a spark gap of almost 54 inches, or 1.37 meters.)

2 **Learn the terminology.** Designing and building a Tesla coil requires understanding certain scientific terms and units of measure. You'll need to understand their purpose and function to properly make a Tesla coil. Here are some of the terms you'll need to know:[3]

- Capacitance is the ability to hold an electric charge or the amount of electric charge stored for a given voltage. (A device designed to hold an electric charge is called a capacitor.) The unit of measure for capacitance is the farad (abbreviated "F"). A farad is defined as 1 ampere-second (or coulomb) per volt. Commonly, capacitance is measured in smaller units, such as the microfarad (abbreviated "uF"), a millionth of a farad, or the picofarad (abbreviated pF and sometimes read as "puff"), a trillionth of a farad.
- Inductance, or self-inductance, is how much voltage an electric circuit carries per the amount of current in the circuit. (High-tension power lines, which carry a high voltage but a low current, have high inductance.) The unit of measure for inductance is the henry (abbreviated "H"). A henry is defined as 1 volt-second per ampere of current. Commonly, inductance is measured in smaller units, such as the millihenry (abbreviated "mH"), a thousandth of a henry, or the microhenry (abbreviated "uH"), a millionth of a henry.
- Resonant frequency, or resonance frequency, is the frequency at which the resistance to transfer of energy is at a minimum. (For a Tesla coil, this is optimum operating point for transferring electrical energy between the primary and secondary coils.) The unit of measure for the resonant frequency is the hertz (abbreviated "Hz"), defined as 1 cycle per second. More commonly, the resonant frequency is measured in kilohertz (abbreviated "kHz"), with a kilohertz being equal to 1000 hertz.

3

Gather the parts you'll need. You'll need a power supply transformer, a high-capacitance primary capacitor, a spark gap assembly, a low-inductance primary inductor coil, a high-inductance secondary inductor coil, a low-capacitance secondary capacitor and something to suppress, or choke, the high-frequency noise pulses created when the Tesla coil operates. For more information on the parts, see the next section, "Making a Tesla Coil."

- Your power source/transformer feeds power through the chokes to the primary, or tank circuit, which connects the primary capacitor, primary inductor coil and spark gap assembly. The primary inductor coil is placed adjacent to, but not wired to, the inductor coil of the secondary circuit, which is connected to the secondary capacitor. Once the secondary capacitor has built up sufficient electric charge, streamers of electricity (lightning bolts) discharge from it.

Part 2 Making a Tesla Coil

1 **Choose your power supply transformer.** Your power supply transformer determines how large you can make your Tesla coil. Most Tesla coils operate with a transformer that puts out a voltage between 5,000 to 15,000 volts at a current between 30 and 100 milliamperes. You can obtain a transformer from a college surplus store or from the Internet, or cannibalize the transformer from a neon sign.[4]

2 **Make the primary capacitor.** The best way to create this capacitor is to wire a number of small capacitors in series so that each capacitor handles an equal share of the total voltage of the primary circuit. (This requires that each individual capacitor have the same capacitance as the other capacitors in the series.) This kind of capacitor is called a multi-mini-capacitor or MMC.

- Small capacitors, and their associated bleed resistors, can be obtained from electronics supply stores, or you can scrounge for ceramic capacitors from old television sets. You can also make the capacitors out of sheets of polyethylene and aluminum foil.
- To maximize the power output, the primary capacitor should be able to reach its full capacitance each half-cycle of the frequency of the power being supplied to it. (For a 60 Hz power supply, this means 120 times each second.)

3 **Design the spark gap assembly.** If you're planning on a single spark gap, you'll need metal bolts at least a quarter-inch (6 millimeters) thick to serve as the spark gap to withstand the heat generated by the discharge of electricity between the sparks. You can also wire multiple spark gaps in series, use a rotary spark gap or blow compressed air between the sparks to moderate the temperature. (An old vacuum cleaner can be used to blow the air.)

4 **Build the primary inductor coil.** The coil itself will be made of wire, but you'll need something to wrap the wire around in a spiral shape. The wire should be enameled copper wire, which you can obtain from an electrical supply store or by cannibalizing the outlet cord from a discarded appliance. The object you wrap the wire around can be either cylindrical, such as a cardboard or plastic tube, or conical, such as an old lampshade.

- The length of the cord determines the inductance of the primary coil. The primary coil should have a low inductance, so you'll use comparatively few turns in making it. You can use non-continuous sections of wire for the primary coil, so that you can hook sections together as necessary to adjust the inductance on the fly.

5 **Connect the primary capacitor, spark gap assembly and primary inductor coil together.** This completes the primary circuit.

6 **Build the secondary inductor coil.** As with the primary coil, you're wrapping wire around a cylindrical shape. The secondary coil must have the same resonant frequency as the primary coil for the Tesla coil to operate efficiently. However, the secondary coil must be taller/longer than the primary coil because it has to

have a larger inductance than the primary coil, and also to prevent any electrical discharge from the secondary circuit to strike and fry the primary circuit.

- If you lack the materials to make the secondary coil tall enough, you can compensate by building a strike rail (essentially a lightning rod) to protect the primary circuit, but this will mean that most of the Tesla coil's discharges will hit the strike rail and not dance in the air.

7 **Make the secondary capacitor.** The secondary capacitor, or discharge terminal, can be any round shape, with the 2 most popular being the torus (ring or donut shape) and the sphere.

8 **Attach the secondary capacitor to the secondary inductor coil.** This completes the secondary circuit.

- Your secondary circuit should be grounded separately from the grounding for your household circuits supplying power to the transformer to prevent a stream of electric current from traveling from the Tesla coil to the ground for your household circuits and possibly frying anything plugged into those outlets. Driving a metal spike into the ground is a good way to do this.

9 **Build the pulse chokes.** Chokes are simple, small inductors that keep the pulses created by the spark gap assembly from wrecking the power supply transformer. You can make one by winding thin copper wire around a narrow tube, such as a disposable ball point pen.

10 **Assemble the components.** Place the primary and secondary circuits next to each other, and connect the power supply transformer to the primary circuit through the chokes. Once you plug the transformer in, your Tesla coil is ready to run.

- If the primary coil is of sufficiently large diameter, the secondary coil can be set inside it.

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Community Q&A

How can I raise the Tesla coil to its highest voltage possible?

wikiHow Contributor

Once you build a Tesla coil, you should make sure you have it tuned properly so the resonant frequencies of the primary and secondary coil are the same. Adding capacitors, getting a NST with more volts out, or making the secondary coil higher can also help.

Not Helpful 7 Helpful 27

How can I generate a Tesla tower with a power of up to 12 volts?

wikiHow Contributor

12 volts may be insufficient to ionize the dielectric strength of air (medium between spark gaps.)

Not Helpful 11 Helpful 33

Can I make a Tesla coil using a 1kV transformer and 5.25 PVC pipe? If it works, what would be its effective range?

wikiHow Contributor

If possible use full bridge rectifier and capacitor and use 30 gage wire, not thinner than that.

Not Helpful 3 Helpful 13

Can a 9 volt battery be used to make a smaller Tesla coil?

wikiHow Contributor

You can with the correct transformer, like from a bug zapper.

Not Helpful 10 Helpful 27

How do I make a bigger, 5 foot tall Tesla coil?

wikiHow Contributor

Scale up this design. Make sure you have enough power. A larger coil -- including anything of 5 or 6 feet and up -- will require huge amounts of electricity, and can easily become very dangerous. For these and other reasons, you should strongly consider starting with a much smaller project.

Not Helpful 7 Helpful 18

Is making a spark gap compulsory? Can it work without the spark gap?

wikiHow Contributor

Yes, but it is an entirely different type of Teslas known as SSTC (solid-state-tesla-coils) which requires heavy transistors or MOSFET's, which may be too expensive for beginners.

Not Helpful 6 Helpful 15

What's the lowest possible voltage for a Tesla coil?

wikiHow Contributor

There is no minimum, as long as your transformer makes the voltage high enough to ionize the air.

Not Helpful 7 Helpful 12

Can I make a Tesla coil that will provide electricity for a family home?

wikiHow Contributor

A Tesla coil can't create electricity, it is just a wireless transmitter. We don't use it this way though, because some energy is lost in the air, so it is not a very efficient solution.

Not Helpful 1 Helpful 4

What is the cheapest way to make a Tesla coil?

wikiHow Contributor

You can always head over to a scrap yard and try your luck there. Also, places like eBay, Craigslist, and Willhaben, sell several components for cheap. Not the safest, most surefire way, but still cheaper than buying new parts.

Not Helpful 1 Helpful 4

How can I increase the efficiency of a Tesla coil?

wikiHow Contributor

You can do that by decreasing resistance. If you have 12-volt supply, use 22 k resistor, use 38 gauge or thinner (but not more than 42 gauge) copper wire; if you can, replace copper wire with gold or silver. If you have 110-volt, use a full bridge rectifier and use only 36 gauge wire and 29 k resistor; do not use gold, only silver.

Not Helpful 6 Helpful 3

Tips

- To control the direction of the streamers erupting from the secondary capacitor, place metal objects near, but not touching, the capacitor. The streamer will arc from the capacitor to the object. If the object includes a light, such as an incandescent bulb or fluorescent tube, the electricity coming from the Tesla coil will make it light up.
- Designing and building an efficient Tesla coil requires working with fairly complex mathematical equations. Fortunately you can easily find the pertinent equations and online calculators to do the math involved.[5]

Warnings

- Making a Tesla coil is not an easy task unless you already have some engineering and electronics knowledge.
- Solid Neon sign transformers, such as recently manufactured ones, tend to include a ground fault circuit interrupter; therefore, they won't be able to operate the coil.
- A capacitor used for Tesla coils and other high voltage and ion generators or devices like *Lifter.'* Can accumulate and retain massive amounts of electric energy and discharge all energy in an instant. Use extreme warning and don't let children or anyone who have no proper safety training.

Things You'll Need

- [ ] Power supply transformer (Neon sign transformer or pole pig)
- [ ] Ceramic capacitors
- [ ] Metal bolts
- [ ] Fan or blower (optional)
- [ ] Enameled copper wire
- [ ] Cylindrical or conical shaping forms
- [ ] Ring- or spherical-shaped metal object
- [ ] Grounding spike
- [ ] Strike rail (optional)
- [ ] Pulse chokes

Sources and Citations

1. http://www.pbs.org/tesla/ins/lab_tescoil.html

2. http://deepfriedneon.com/tesla_guide.html
3. http://www.serrata.com.au/Support/downloads-2/files/1055022.pdf

Show more... (2)

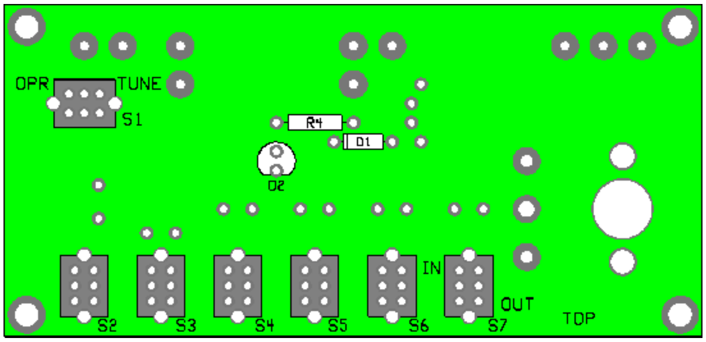
Pacific Antenna SLT+ Switched Long wire Tuner

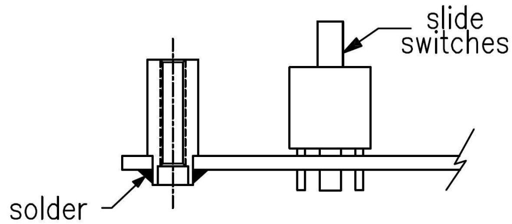
The SLT+ is designed to match the high impedance load of an end feed, half wave antenna wire to a 50 ohm transmitter using manually switched inductors and a variable capacitor configured in a “L” matching network. Six inductors in BCD weighted values allows for selecting inductor values from 0.5 uHy to 23.5 uHy in 0.5 uHy steps. A resistive SWR bridge with LED indicator is built in so an external SWR bridge is not required to find the match. This tuner and end feed antennas are ideal for field operation of QRP rigs.

Parts list:		
Quantity	Designation	Value/ description
1	Circuit board	
7	S1-8	DPDT slide switches
3	R1,R2,R3	51 ohm, 2W resistors
1	R4	470 ohm 1/4W resistor
1	D1	SD101 diode
1	LED	Clear, ultra bright LED
1	T1	FT37-43 ferrite core (black)
2	L1 ,L2	T50-2 RED toroid core (large)
4	L3,4,5,6	T37-2 RED toroid core (small)
1	C1/C2	Poly-variable tuning cap
1 set		Knob, 3 screws, and nylon spacer for poly-varicon.
8 feet		Red #28 magnet wire
9”		Green #28 magnet wire
1		Red 5 way binding post
1		Black 5 way binding post
1		BNC jack
4		3/16” Swage board standoff, #2
4		1/4” #2 flat head screws
1		Case
		Set of decals

Construction:

Parts are mounted to both the top and bottom side of the circuit board. We will start with the top side.

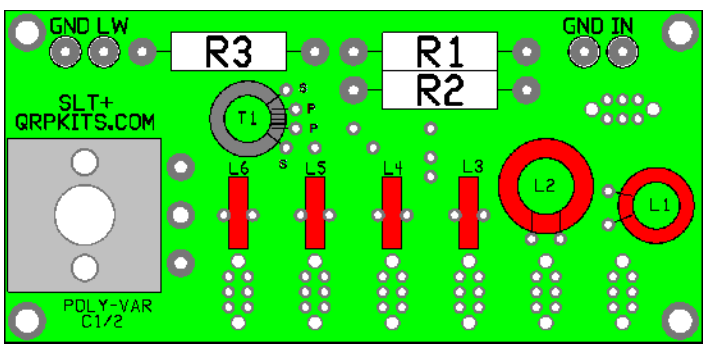




Install standoffs on topside of the board, and solder on bottom side.

1. Install the four (4) 0.187" Swag standoffs into the four mounting holes in the corners of the board. These are inserted from the **TOP SIDE** of the board. Run a bead of solder around the outside edge of the standoffs sticking out the **BOTTOM** of the board to attach them to the solder pad around them. You will need a fairly high wattage iron to do this.
2. Install the seven (7) DPDT slide switches on the top side of the board.
3. Install R4, 470 ohm resistor (Yellow, Violet, Brown, Gold)
4. Install D1, SD101 glass diode
5. Install the LED. Be sure to match up the flat on one side of the LED package with the flat side of the LED outline on the board. Do not mount the LED flush to the board. With the board flipped over so that you can solder the leads, let the top of the LED touch your work bench so that it is the same height as the top of the switch levers.

Bottom side of board:



1. Wind and install T1. Wind the 25 turn secondary first (16" of red wire) on the BLACK T37-43 ferrite core. Then wind the 5 turn (9" of green wire) primary in the gap between the secondary turns. See illustration on next page. The leads from the secondary winding go into the top and bottom holes labeled "S" in the diagram and the primary winding leads into the middle holes labeled "P" Be sure to tin the wire ends before trying to solder the wires to the pads on the board. The insulation can be melted through with a hot soldering iron with a blob of solder on the tip and rubbing the wire until the insulation melts. Or, the insulation can be burnt off with a match or lighter, then cleaned up with some fine grit sandpaper or emery cloth.
2. Install R1, R2 and R3 the 51 ohm (Green, Brown, Black, Gold) 2 watt resistors
3. Wind and install L1 and L2. (See table next page for number of turns) These both mount flat to the board. L1 will overhang the edge of the board slightly.
4. Wind and install L3 to L6. These mount vertically on the board.

5. Install the variable capacitor and secure to the board with the two mounting screws. Set the trimmers on the bottom of the cap to minimum setting. (fully unmeshed)

Winding	Table	
L1/L2	T50-2	40 turns (28”)
L3	T37-2	32 turns (18”)
L4	T37-2	22 turns (13”)
L5	T37-2	16 turns (11”)
L6	T37-2	11 turns (8”)

Remember that one turn is each time the wire passes through the center of the core. Evenly space turns around core. Be sure to tin wire ends before soldering to board.

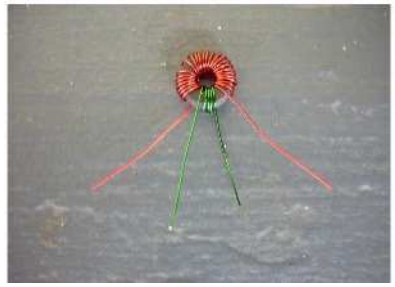


Illustration 1: T1 winding

This competes assembly of the board.

Preparing the case:

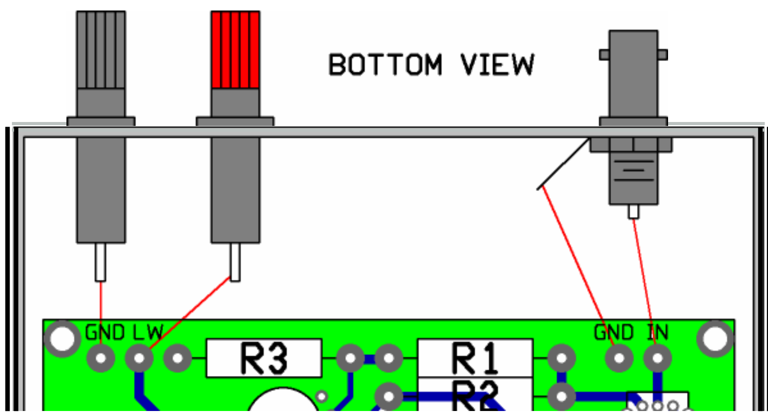
If you like, you can paint the case the color of your choice.

Apply the decals to the case as shown in the picture on page 1 of the manual.

Install the BNC jack and binding posts to the side of the case.

Drop the circuit board into the top of the case and mount using four (4) #2 screws into the standoffs from the top of the case.

Using the resistor lead clippings, jumper the connections from the board to the BNC jack and binding posts.



Pad labeled “IN” goes to the center pin of the BNC jack. Pad labeled “GND” goes to the ground lug on the BNC jack

Pad labeled “LW” goes to RED binding post. Pad labeled “GND” goes to the BLACK binding post

Put bottom cover on case.

Install the nylon spacer and screw onto the tuning capacitor to form a shaft for the knob. A drop of nail polish or super glue on the threads where the screw goes into the cap will help it from becoming loose. Put the knob on the shaft and your are done!

Using the SLT+

For best results, random wire lengths should be avoided. Ideally, the wire length should be about 10% shorter than a 1/2 wave on the band you wish to operate on. An exact 1/2 wave length antenna has a fairly high impedance on the end, which the SLT+ may not be able to match. Making the wire slightly shorter reduces the impedance to something the SLT+ will have an easier time matching. For bands which are harmonically related, a single length of wire will work on these bands. For example, a 1/2 wire on 40 will work as a full wave on 20.

A counter pose wire is recommended. Using a counter pose wire will eliminate any hand capacitance effects which can change the tuning when you remove your hand from the tuner box or rig. The counter pose wire would connect to the ground (black) binding post. Ideally, a 1/4 wave length wire would be used, but good results can be obtained with shorter wires. Lay this wire on the ground and if possible, in a direction opposite the active antenna wire.

The table below shows the approximate value of inductance and capacitance needed to match a wire on different bands. Preset the switches to these values for the band in use and tweak from there. Place the TUNE / OPER switch in the TUNE position to active the SWR bridge. Adjust the tuning capacitor and inductance in order to make the LED dim as much as possible or make it go out all together (best match). Once the match is found, switch back to the OPER (operate) position and start making QSOs!

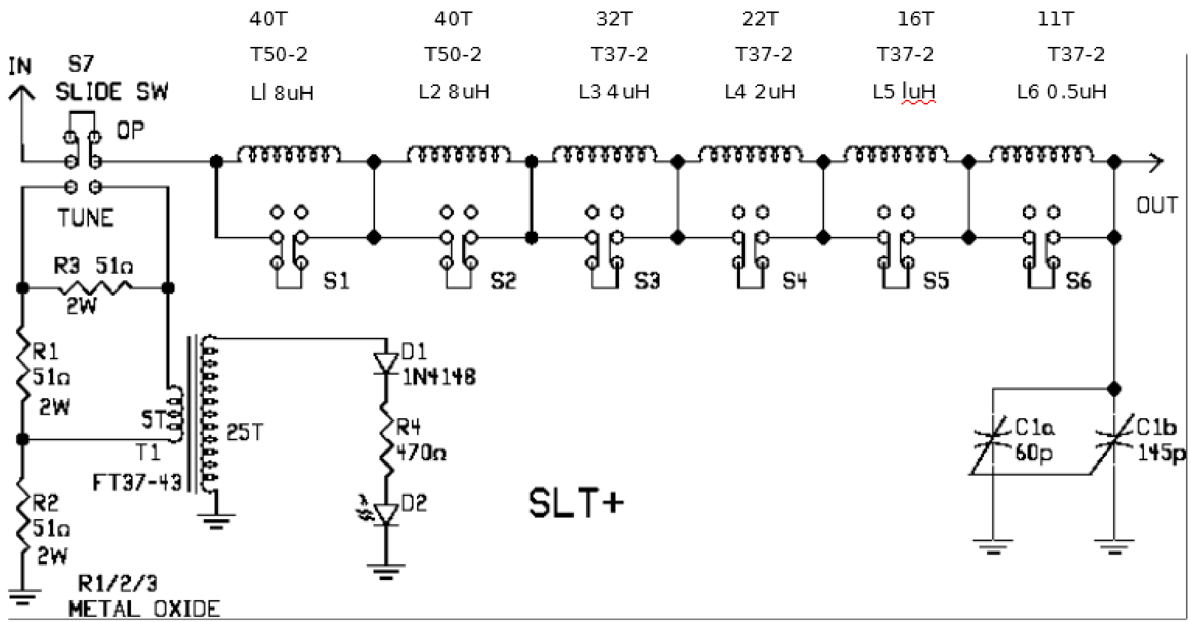
80 M	40 M	30 M	20 M	15 M	10 M
22 uH	12 uH	8 uH	5.5 uH	4 uH	3 uH
100 p	50 p	30 p	25 p	15 p	10 p
Inductor values for switches in “IN” position.					
S1	S2	S3	S4	S5	S6
8 uH	8 uH	4 uH	2 uH	1 uH	0.5 uH

Getting a wire up into the trees:

One of the big advantages of an end feed antenna is the ease and speed it can be erected, compared to dipoles, since only one end of the wire needs to be thrown into the tree. You don't have to find two trees the right distance apart and nothing in between them which would make stretching a wire between them difficult.

The simplest way to get a wire over a tree branch well up off the ground is to use a plastic water or soda bottle 1/3d to 1/2 full of water as a throwing weight. The shape of the bottle is such that it is easy to hold and it slips down between tree branches without snagging or wrapping around branches and getting snagged. Nylon “Mason line” is used as a leader. Simply put one end of the mason line into the top of the bottle and replace the cap. Loosely lay out the line on the ground in such a manner that it will not snag on stuff which might be on the ground. An underhand toss of the bottle is generally the best way to throw it. With a little practice, you should be able to get it at least 20 feet up.

How the wire is configured depends greatly with what you have to work with in terms of support trees. The simplest configuration is an inverted “V” where the wire runs from the tuner, up to a tree branch and back down towards the ground. An “L” configuration is somewhat better for DX, especially if you can get the part of the wire from the tuner up to the tree as vertical and as long as possible. If the wire is run fairly close and parallel to ground, this is good for close in contacts.



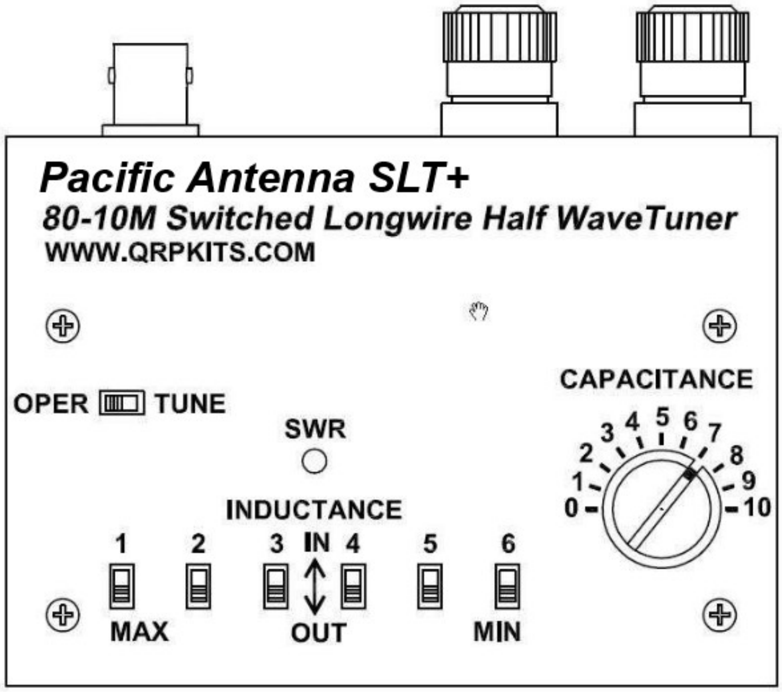
Antenna approximations for CW portion of the bands

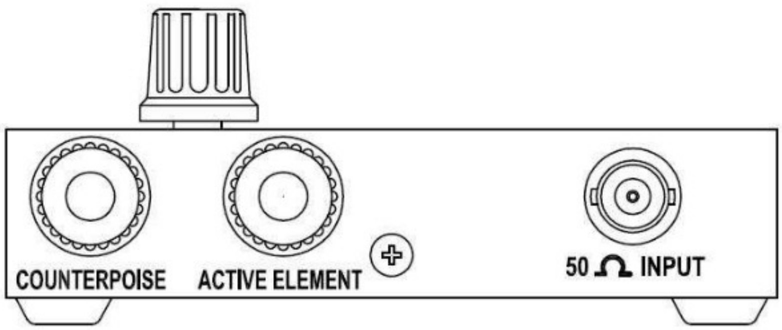
Band	80m	40m	30m	20m	17m	15m	10m
Active Ele.	124 ft.	63 ft.	44 ft.	31.5 ft.	24.5 ft.	21 ft.	15.5 ft.
Counterpoise	69 ft.	35 ft.	24 ft.	17.5 ft.	13.5 ft.	11.5 ft	8.5 ft.
Inductance	S 1,2,3,4	S 1,3	S 1	S 3,5,6	S 3	S 3	S 4,5

Counterpoise should be 180° from active element direction

For best results, use as little inductance as possible, to obtain a match. How the wire is configured depends greatly with what you have to work with in terms of support trees. The simplest configuration is an inverted "V" where the wire runs from the tuner, up to a tree branch and back down towards the ground. An "L" configuration is somewhat better for DX, especially if you can get the part of the wire from the tuner up to the tree as vertical and as long as possible. If the wire is run fairly close and parallel to the ground, this is good for close in contacts.

If you desire, print this out, seal with clear packaging tape, and apply to the bottom of the tuner with two-sided tape for a reminder.





Pacific Antenna SLT + Decal Installation

The decals are applied the same as model decals. Cut around each group of text or symbols you wish to apply, leave a border. It doesn't have to be perfect as the background film is transparent. Apply the decals before you mount anything to the cover. Use the above 1:1 picture to get the correct spacing around the holes, as it is very easy to do a great decal installation and have a portion covered up with a knob. Use the cross in the center of the capacitance group, and center it in the hole

Thoroughly clean the surface of the panel to remove any oils or contamination.

Trim around the decal, leaving about 1/16" space around the printing. After trimming place the decal in a bowl of lukewarm water, with a small drop of dish soap to reduce the surface tension, for 10-15 seconds. Handle carefully to avoid tearing. Start to slide the decal off to the side of the backing paper, and place the unsupported edge of the decal close to the final location. Hold the edge of the decal against the panel, with your finger, and slide the paper out from under the decal. You can slide the decal around to the right position, as it will float slightly on the film of water. Use a knife point or something sharp to do this. When in position, hold the edge of the decal with your finger and gently squeege excess water out from under the decal with a tissue or paper towel. Work from the center, to both sides. Remove any bubbles by wiping gently to the sides. Do this for each decal, and take your time. Allow to set overnight, or speed drying by placing near a fan for a few of hours. When dry, spray two light coats of matte finish, Krylon, clear to seal and protect the decals, and allow to dry in between coats. All decals come with two complete sets, in case you mess one up.

Tune Around!
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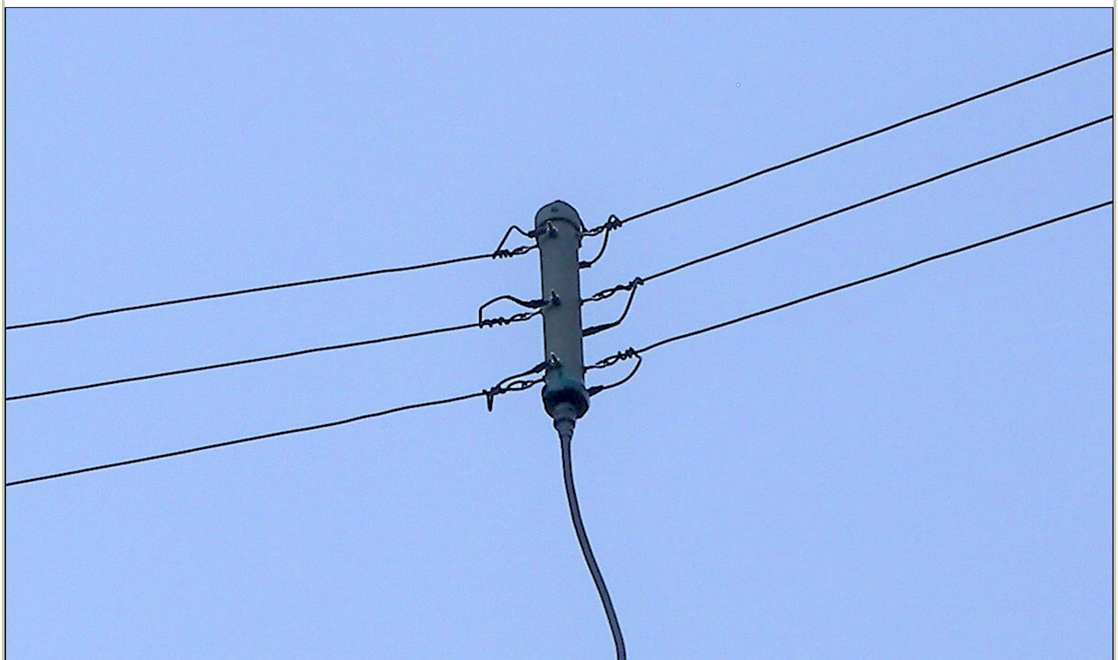
The KL3JM MODIFIED "SRI" MULTIBAND FAN DIPOLE
FOR 80 - 40 - 20 Meters

I built my SRI dipole for three bands, 80, 40 and 20 and designed it to be as light as possible since there would be no center support, just hanging between two trees.



It was based on an article on Hamuniverse.com that can be seen here. In case you don't know what an "SRI" dipole is, read the article above in the link. The antenna in this project is a modification of the techniques used to design a multiband fan type dipole with little or no tuning involved.

Since I only had 105 feet between my trees I had to use a loaded wire for the 80 meter band at 90 feet long.

K7MEM has a good web site at www.k7mem.com that I used to get the specs for this short 80 meter section loading coil.
It was made with a 51uh coil set between a 9 foot and 36 foot wire for a total of 45 feet on each side. This 90 foot length set the design for the rest of the assembly.

The center connector/insulator was made from a 14 inch length of 1 1/4 inch PVC. See photo (1) below.

The 1 1/4 inch PVC is not big enough to get your hand in but much lighter than 3 or 4 inch PVC. While a bit like building a ship in a bottle, it wasn't too bad to get it together.

I used 6 stainless #10 eye bolts as wire anchors and 6 stainless #10 machine screws for the terminal connectors, 3 per side.
The terminals were spaced 6 inches apart, a bit more than the 5 3/4 inch spacing suggested in the original SRI design. (It is important to remember that all 3 center insulator terminals are wired together on each side of the center insulator making each half of the dipole parallel with the other band dipole legs on the same side. Each half of the dipole is connected to the SO-239 connector. One side of ALL of the dipoles is connected to center pin on the S0-239 connector and the side to the shield side of the connector.)

The three terminals for each side were connected with 12 gauge wire with ring terminals. The nuts and washers for the middle terminals and eye bolts were held in place by putting them on the end of a long screw driver with a bit of axel grease to hold them on the tip.

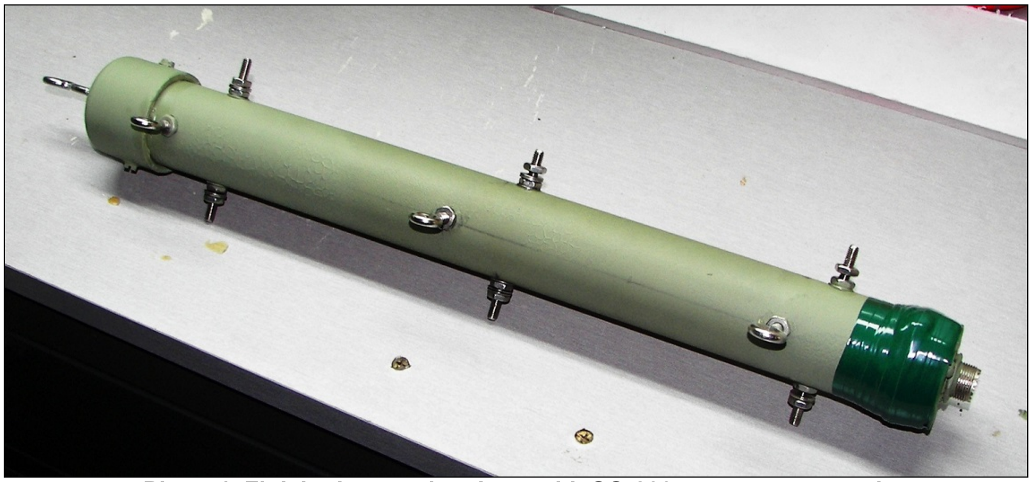
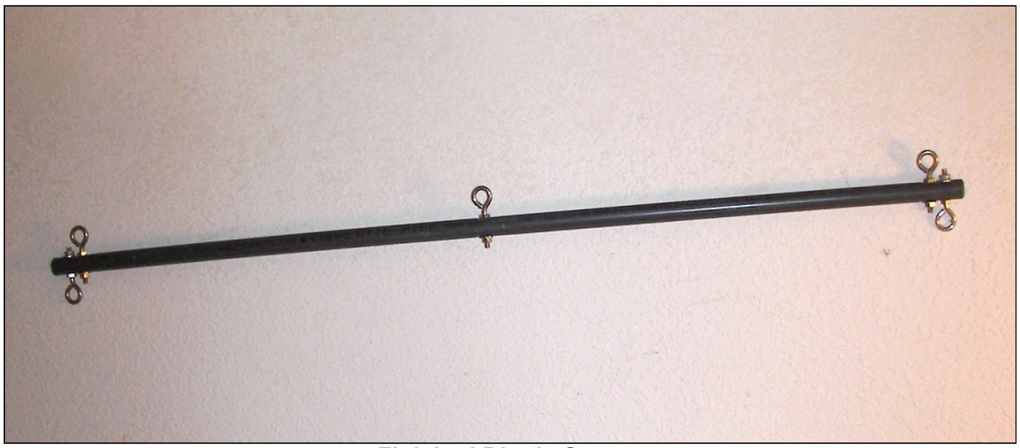


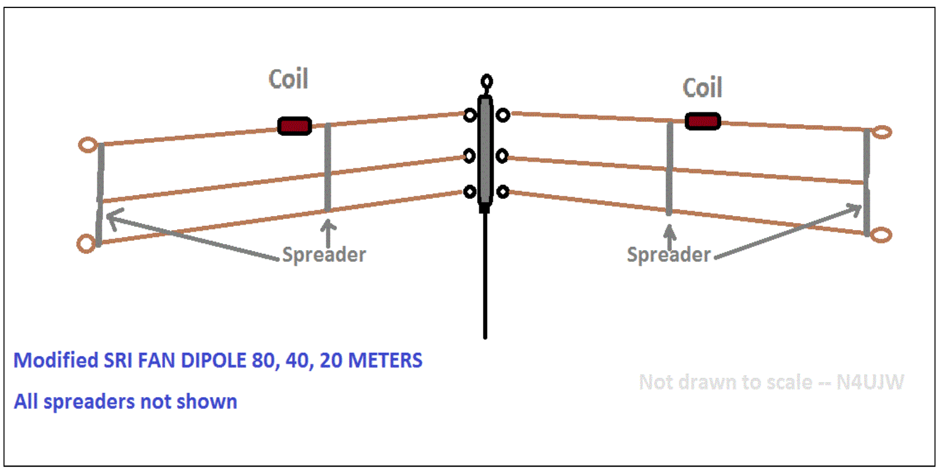
**Photo 1. Finished center insulator with SO-239 connector on end.
Dipole terminals spaced 6 inches apart.**



Finished Dipole Spacer

Note that the spacing between each dipole on the end spacer is 19.5 inches between each wire as suggested by the army's total length of 39 inches in the [original SRI article](). Although not mentioned in the article, small diameter PVC tubing can be used for the spacers (sometimes called spreaders) between dipoles or any non-conductive material.

Yellow drawn in lines represent separate dipoles with spacers.
80 meter coil is in upper right of picture.



I built the antenna on the ground and tuned all three bands with my MFJ analyzer.
The 80 meter wire started at 45 feet per side, the 40 meter wire at 32 1/2 feet per side and the 20 meter wire at 17 feet per side.

Starting with the analyzer on the top wire, each band needed to be shortened a bit. After about 5 adjustments all bands were resonant in the middle of the band with an SWR of 1.3 or less.

After raising the antenna up 64 feet to its final position and putting the analyzer back on, there was no need to lower it for more tuning. The same resonant points stayed as they were with SWR at 1.3 for the 20 and 40 bands and 1.8 for the 80 meter band. I have made a number of good contacts between Fairbanks and Miami with signal reports of S-6 to S-9 on all 3 bands.

I found this to be a simple and inexpensive multi band antenna to construct and I am very happy with the results.

73

Scott KL3JM
Don't forget to refer to the original SRI article on Hamuniverse.com

Email Scott for any questions here>> novak AT gci.net

Pacific Antenna 40M Easy Receiver Kit

Description

The Easy Receiver kit from Pacific Antenna is designed to be easy to build and use. It covers approximately 75kHz of the 40M band and can be assembled in about 1-2 hours.

It has no toroids to wind and only one adjustment (trimcap) to set the frequency.

It is a direct conversion design employing a front end bandpass filter, NE602 mixer and LM386 audio amplifier.

Our Easy Receiver is designed to work with our Easy Transmitter, Easy Audio Filter, Easy Tuner and Easy Keyer and Easy TR switch to make a complete QRP station.

These boards are designed so that, if desired, they can be stacked together to produce a compact assembly.

Support

PACIFIC ANTENNA
Web:www.qrpkits.com
Email: qrpkits.com@gmail.com

Tools Needed

- □ Soldering Station or 15-35 watt soldering iron with small tip.
- □ Solder 60/40 or 63/37 Tin-Lead
- □ Small Diagonal Cutters
- □ Small Needle Nose Pliers
- □ Pencil, Pen, and/or Highlighter
- □ BRIGHT work light

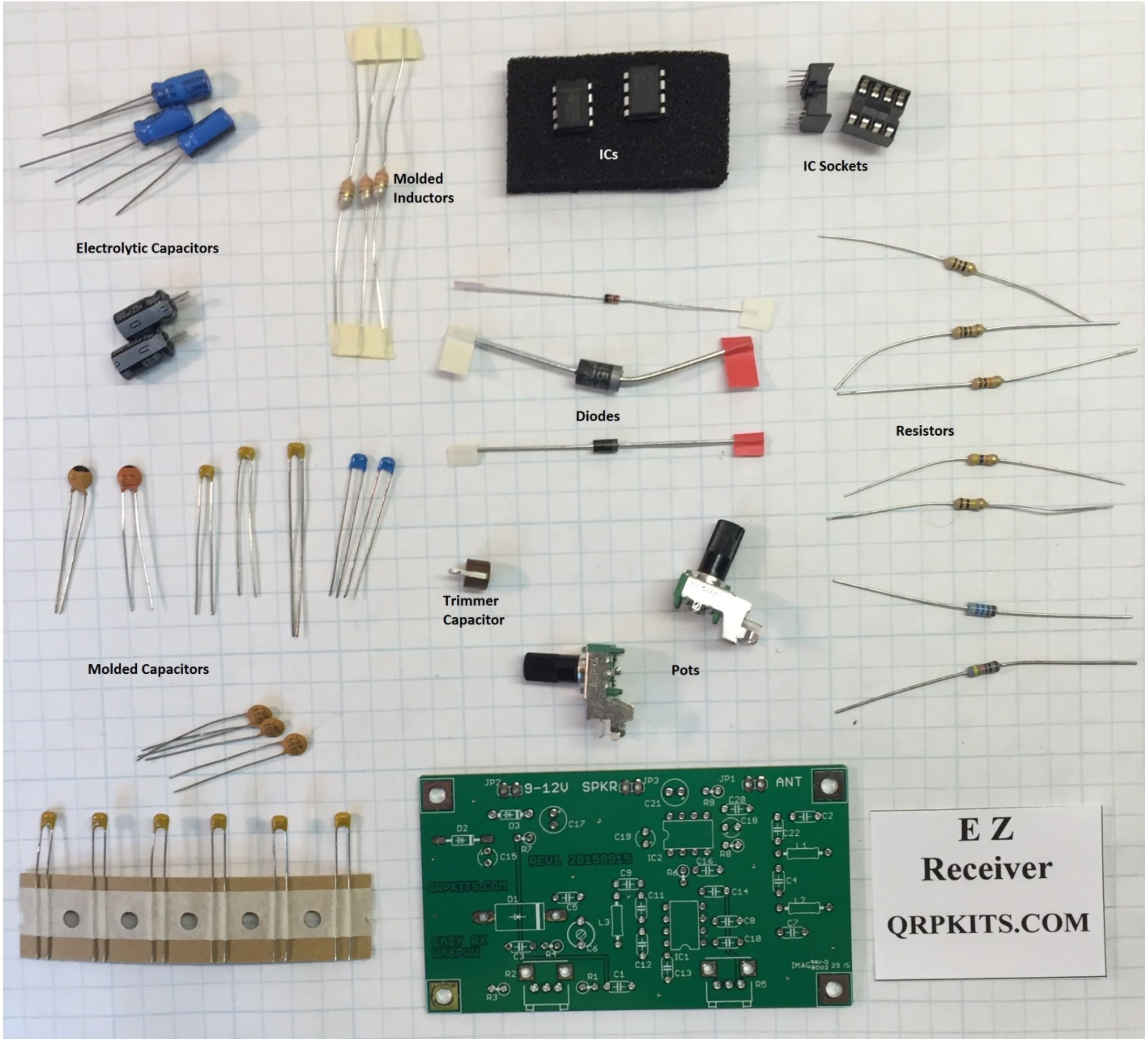
Optional

- □ Magnifying headpiece or lighted magnifying glass.
- □ Multi-meter
- □ Solder Sucker and/or Solder Wick
- □ Small multi-blade Screw Driver
- □ Knife or Wire Stripper
- □ Small Ruler
- □ Cookie Sheet to build in and keep parts from jumping onto the floor.

Construction Techniques

- □ There is no need to print out the whole assembly manual unless you want a copy. Print the Parts List and Schematic then view the rest of the manual on a computer, laptop, or tablet.
- □ The Parts List has columns for inventory and construction.
- □ Please take time to inventory the parts before starting. Report any shortages to QRPKITS.com (In many cases it may be faster and cheaper to pull a replacement from your parts supply, but please let us know if we missed something.)
- □ Use the first column to check the parts as you inventory them.
- □ Use the second column to check the parts as you install them.
- □ Pre-sorting the resistors and capacitors can speed up the assembly and reduce mistakes.
- □ You can insert several parts at a time onto the board. When you insert a part bend the leads over slightly to hold the part in place, then solder all at the same time. Clip the leads flush.
- □ Most parts should be mounted as close to the board as possible. Transistors should be mounted about 1/8" above the board. Solder one lead on ICs or IC sockets and then check to make sure the component is flush before soldering the remaining leads.
- □ If you are a beginner, new to soldering, there are a number of resources on the web to help you get on the right track soldering like a pro. Google Soldering Techniques.

Parts Identification:



Note: Parts included in the kit may vary slightly from those shown in photograph. This is due to changes in manufacturers or suppliers and does not affect the kit performance.

Inventory and Parts List

Inventory	Inst.	Qty	Parts	Value	Identification	Description
		1	R9	10 Ohm	brn-blk-blk-gold	RESISTOR, 1/4W , 5%
		1	R7	150 Ohm	brn-grn-brn-gold	RESISTOR, 1/4W , 5%
		1	R8	10K Ohm	brn-blk-org-gold	RESISTOR, 1/4W , 5%
		1	R6	47K Ohm	yel-vio-org-gold	RESISTOR, 1/4W , 5%
		1	R4	100 K Ohm	brn-blk-yel-gold	RESISTOR, 1/4W , 5%
		1	R10	33 K Ohm	Org-org-org-gold	RESISTOR, 1/4W , 5%
		1	R1	4.75K 1%	yel-vio-grn-brn-brn	RESISTOR, 1/4W, 1%
		1	R3	432 1%	yel-org-red-blk-brn	RESISTOR, 1/4W, 1%
		1	C4	4.7pF	4.7	CAPACITOR, disk ceramic
		1	C5	27pF	27	CAPACITOR, disk ceramic
		1	C7	150pF	151	CAPACITOR, monolythic
		1	C22	180pF	181	CAPACITOR, monolythic
		1	C9	220pF	221	CAPACITOR, monolythic
		2	C11, C12	470pF	471	CAPACITOR, monolythic
		3	C2, C10, C16	1000pF	102	CAPACITOR, monolythic
		6	C1, C3, C8, C13, C14, C20	0.1uF	104	CAPACITOR, monolythic
		3	C15, C18, C19	10uF	10 uf	ELEC. CAPACITOR 25V+
		2	C17, C21	100uF	100uf	ELEC. CAPACITOR 25V+
		3	L1, L2, L3	3.3uH	org-org-gold-silver	INDUCTOR, molded
		1	D2	1N5234	234B (glass body)	DIODE, Glass
		1	D1	1N5401	1N5401	DIODE, Large Black Plastic
		1	D3	1N5817-B	1N5817	DIODE, Small Black Plastic
		2	SC	Sockets		IC Sockets, 8 pin
		1	IC2	LM386N-4	LM386N	Audio Power Amplifier, 8 pin Ic
		1	IC1	NE602	NE602A	NE602 or SA612, 8 pin IC
		1	C6	50pF	brn	Trimmer capacitor, brown
		1	R5	10K A	A10K	Green Potentiometer, Volume
		1	R2	10K B	B10K	Green Potentiometer, Tuning
		1	BNC	BNC		BNC Antenna Connector
		1	Phone Jack	Audio		3.5mm Mono Audio Jack
		1	Battery Conn.	9V		9V Battery Connector
		12”	Wire	Wire	2-12 inch sections	Hookup wire, 2 colors
		2	Knob	Knobs	.55” knobs	Small Knobs for Potentiometers
		1	PCB	PCB	Rev 1A or B	Easy RX Circuit Board

Inserting the Parts

First, install the two IC sockets, making sure to match the end with the notch to the board outline.

□	2	SC	Sockets	IC Sockets, 8 pin

Resistors

Sort the resistors by value insert and solder them smallest value first, largest value last. Be sure to check the color code for each resistor as you install. [Measuring with an Ohm meter is also a good idea.]

□	R9	10 Ohm	brn-blk-blk-gold
□	R7	150 Ohm	brn-grn-brn-gold
□	R8	10K Ohm	brn-blk-org-gold
□	R10	33K Ohm	org-org-org-gold
□	R6	47K Ohm	yel-vio-org-gold
□	R4	100 K Ohm	brn-blk-yel-gold
□	R1	5.75K 1%	yel-vio-grn-brn-brn
□	R3	432 1%	yel-org-red-blk-brn

Ceramic and Molded Capacitors

First insert and solder the molded capacitors.

□	C4	4.7pF	4.7	CAPACITOR, disk ceramic
□	C5	27pF	27	CAPACITOR, disk ceramic
□	C7	150pF	151	CAPACITOR, monolithic
□	C22	180pF	181	CAPACITOR, monolithic
□	C9	220pF	221	CAPACITOR, monolithic
□	C11	470pF	471	CAPACITOR, monolithic
○	C12	470pF	471	CAPACITOR, monolithic
□	C2,	1000pF	102	CAPACITOR, monolithic
○	C10	1000pF	102	CAPACITOR, monolithic
○	C16	1000pF	102	CAPACITOR, monolithic
□	C1	0.1uF	104	CAPACITOR, monolithic
○	C3	0.1uF	104	CAPACITOR, monolithic
○	C8	0.1uF	104	CAPACITOR, monolithic
○	C13	0.1uF	104	CAPACITOR, monolithic
○	C14	0.1uF	104	CAPACITOR, monolithic
○	C20	0.1uF	104	CAPACITOR, monolithic

Electrolytic Capacitors

Now insert and solder the electrolytic capacitors. These capacitors are polarized. The positive hole is marked on the circuit board with a + symbol. The negative lead of the capacitor is also marked with a black bar on the side of the capacitor. This lead should go in the pad away from the + marking.

□ C15 10uF 10uF ELECTROLYTIC CAPACITOR 25V+
□ C18 10uF 10uF ELECTROLYTIC CAPACITOR 25V+
□ C19 10uF 10uF ELECTROLYTIC CAPACITOR 25V+
□ C17 100uF 100uF ELECTROLYTIC CAPACITOR 25V+
○ C21 100uF 100uF ELECTROLYTIC CAPACITOR 25V+

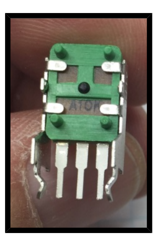
Remaining Parts

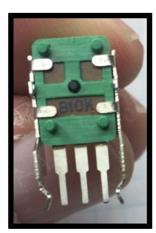
□ L1 3.3uH org-org-gold-silver INDUCTOR, molded
□ L2 3.3uH org-org-gold-silver INDUCTOR, molded
□ L3 3.3uH org-org-gold-silver INDUCTOR, molded
□ D2 1N5234 234B (glass body) DIODE
□ D1 1N5401 1N5401 (Large Black) DIODE
□ D3 1N5817 1N5817 DIODE
□ IC2 LM386N Audio Power Amplifier, 8 pin Ic"
□ IC1 NE602A NE602, 8 pin IC

□ C6 50pF brown trimmer capacitor,
Note: C6 has a flat and round side. It should be installed so that the flat side is oriented toward C5

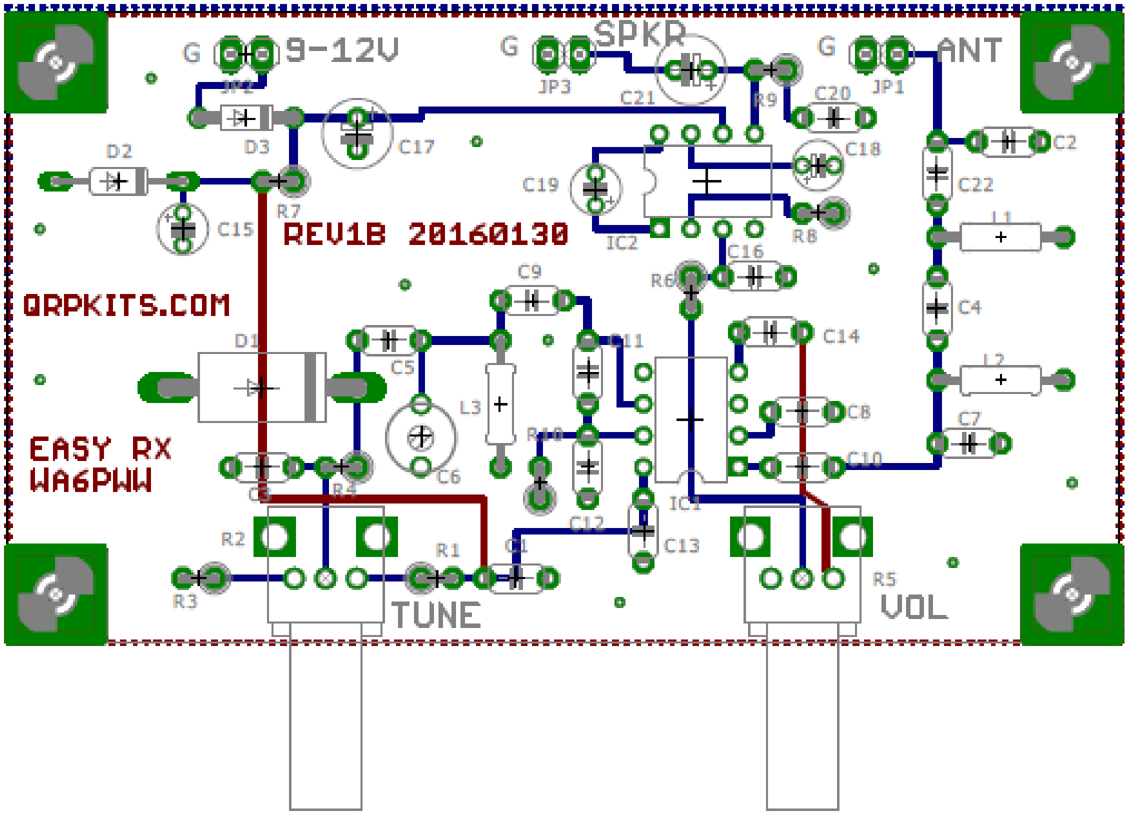
The last parts to install are the potentiometers. The A10K and B10K identification marks are on the back of the pots and are a bit difficult to read. Use lots of light. The pot marked A10K is the 10K Audio Pot. The pot marked B10K is the Linear Pot.

□ R5 A10K Green Potentiometer, Horizontal, Audio
□ R2 B10K Green Potentiometer, Horizontal, Linear





Board Layout



Final Assembly and Packaging

Your easy receiver kit is now completed. Packaging is left up to the builder. However, for testing, you will find included in the package, an audio connector, 9V battery connector and a BNC along with hookup wire. For initial testing, you can just temporarily connect short wires to the board pads and use alligator leads for connection of antenna and audio out.

Connections are shown by the diagram below

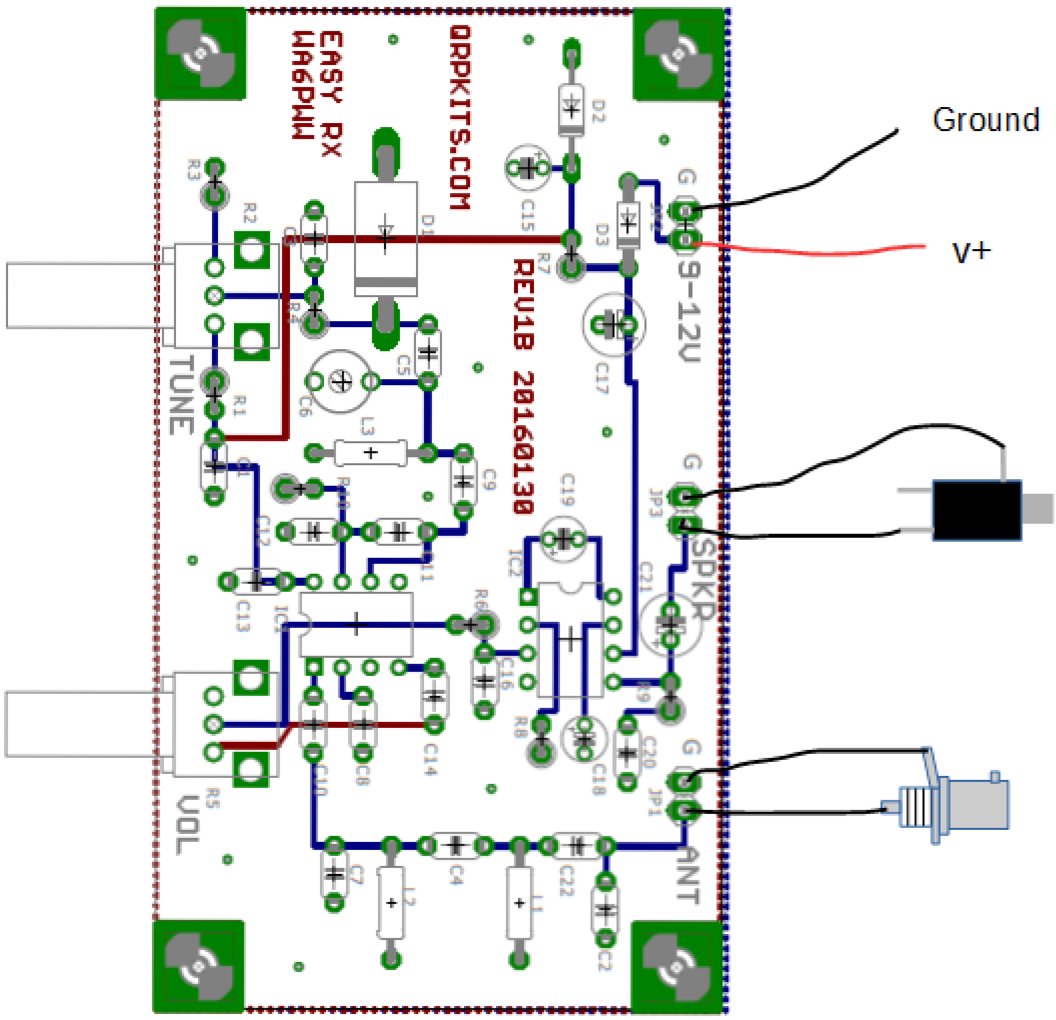
To power your receiver, you will need to supply a source of clean dc power in the range of 9-12V to JP2. This can be from a battery source or a well filtered dc supply. An inline fuse of 1A or less is recommended if a DC supply or 12V battery is used. An inline fuse along with diode D3 serves to protect against reverse polarity damage to the receiver components.

For REV1B and later boards, the connections for power audio and antenna input along with ground are labeled on the board. For earlier board versions, verify by looking at the back of the board to determine which pin is ground as it differs from the REV1B layout shown above.

A speaker or headphone jack should be connected to JP3as shown by board labels. The supplied audio jack is for 3 pin stereo headphones or amplified speakers so the ring and tip should be connected together at the jack for both channels to be fed audio from the single output of the receiver.

Antenna input is through JP1. The BNC connector that is supplied can be used for connecting an external antenna or alternatively, a section of wire at least 8-10ft long can just be connected to JP1 as a temporary antenna.

Connections to Board



Setup and Testing

The Easy Rx has a tuning range of approximately 50-75kHz. This will cover the low end of 40M for example where most of the CW activity is found including QRP frequencies such as 7.030 and 7.040.

First verify that when you power up the Easy Rx, and connect an antenna or section of wire, you should hear static and maybe some signals in the headphones. Turning R2 (the left side potentiometer) will change the received frequency and R5 (the right side potentiometer) will adjust the volume of the background static and any signals received.

To setup the receiver for the desired frequency range, only one adjustment is required. This is to set the trim capacitor C6. This step will be aided if you have a receiver that covers the same band and has capability for receiving CW signals.

As the Easy receiver is a direct conversion design, its oscillator runs continuously and can be heard on any nearby receiver. In this case, an antenna lead connected to the nearby receiver can be placed near the Easy Rx board and you will hear a tone on the receiver corresponding to the local oscillator frequency of the Easy Rx.

To adjust C6, ideally you should use a plastic tool. However, if the trim-cap is installed correctly, (with the flat side toward C5) the part you are touching is grounded and therefore, a small metallic screwdriver will be OK to use.

If using a receiver, tune it to a frequency such as 7.025 or other frequency on which you want the Easy Rx reception range to be centered. Place R2 (the tuning knob on the left) to the middle of its range and then turn C6 slowly. You should hear a tone as the local oscillator of the Easy Rx moves across your other receiver. You will need to turn very slowly and listen carefully as it may move quickly across the desired frequency.

Once you hear a tone on your receiver, stop adjusting C6 and you should hear a steady tone in your other receiver. You can now connect an external antenna to the Easy Rx and use R2 to tune around. If the band is active, you should hear some CW signals.

To set the lower range to a desired frequency, rotate the tuning control (R2) fully counterclockwise. This will place it at the lowest frequency. Then using your external receiver set to the lowest frequency you want to use (such as 7.00 MHz for 40 meters) adjust C6 until you hear the Easy Receiver oscillator as a tone in your receiver. Turning R2 clockwise will move up in frequency and you should be able to tune up to approximately 7.075 MHz with R2 fully clockwise.

A crystal controlled transmitter can also be used as a signal source for setting the frequency of the Easy Rx. To do this, you would simply activate the transmitter, preferably into a dummy load so not to cause interference to others. With a short wire or antenna connected to the Easy RX, set R 2 to the middle of its range and tune C6 while listening for the transmitter tone.

Troubleshooting

The easy RX is designed to be a simple kit to build and to use. However, occasionally, problems may happen. In our experience, these are often soldering issues (shorts or cold solder joints) or component misplacement Here are a few things to check if the kit does not function as it should.

1. Verify component placement, including resistors and capacitors

2. Inspect all solder joints with a magnifying glass, looking particularly for any that may have small whisker shorts or which look dull and blotchy indicating a cold solder joint.

2. Verify orientation of the two ICs in their sockets. One end of the sockets will have a notch and that should be on the same end as the notch in the IC package as well as a dot or other marking for pin 1 of the IC. See the photo on page 3 and diagram on page 7 for examples of proper orientation.

3. Check for correct DC voltages to ground at the following points in the circuit:

-Right side of JP2- should be equal to power supply voltages

-Band end of D3- should be equal to power supply minus approximately 0.7V

-Pins 8 of IC1- should be approximately 6.2V

Pin 6 of IC2 -should be equal to power supply minus approximately 0.7V

If the Easy RX only makes a low level HISS in the speaker or headphones, check the local oscillator operation by placing it near another receiver and listening for the Easy RX local Oscillator. Tune C6 if needed to locate the oscillator in the second Receivers pass band. If there is no oscillator signal then carefully check the circuit around the IC1, NE602/612, to be sure the parts are correct and properly soldered.

If during tune up the local oscillator could be heard in the second RX but the Easy RX has no output from the speaker/headphones then first touch the junction of R6/C16 the speaker should make a 60 HZ humming sound. If this happens then check the parts and soldering around the volume control. If there is no HUM then check the parts and soldering around IC2, LM386.

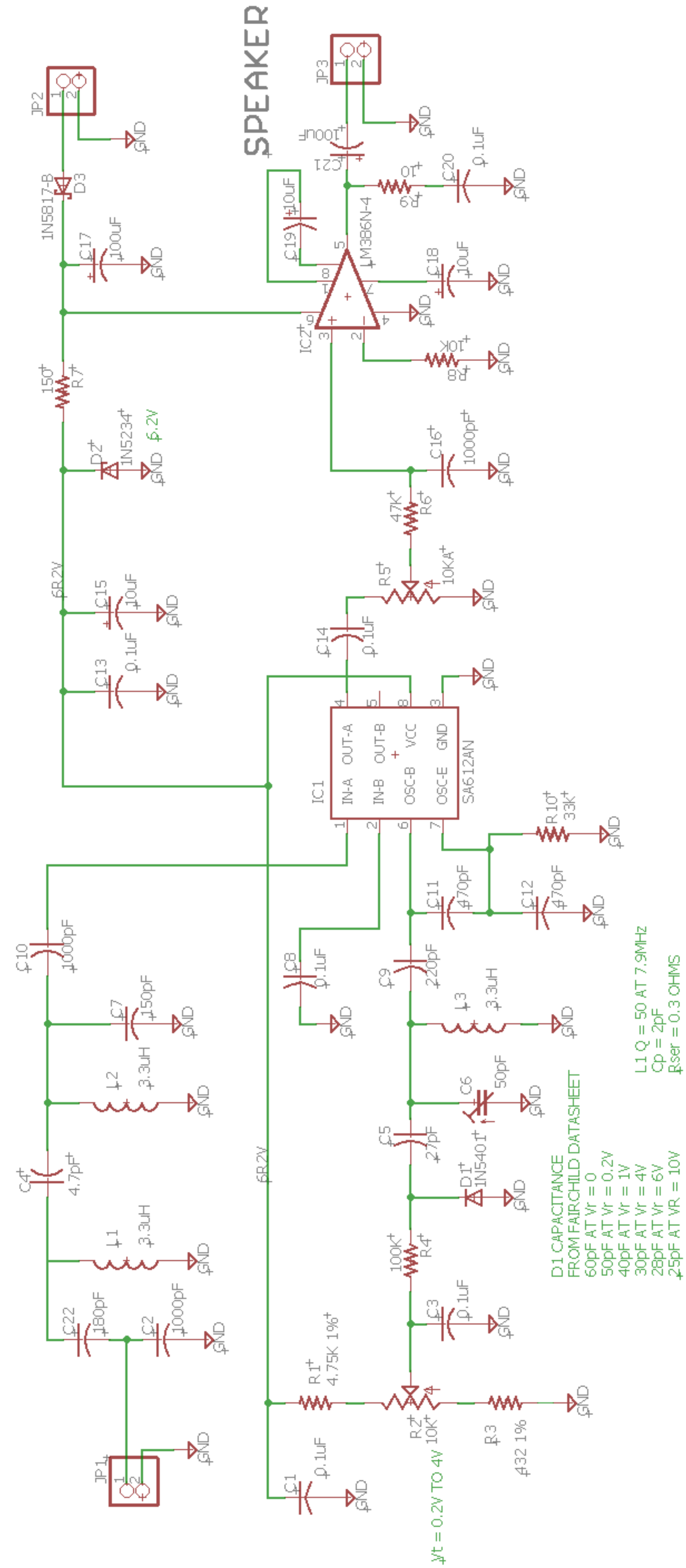
If the receiver is functioning and connected to a good antenna, you should be able to hear CW signals when tuning across the band. You will note that each signal will appear twice as you tune. This is expected for a direct conversion receiver as it will hear the signal on both sides of the center frequency.

As you tune up in frequency and hear a signal, you will hear the signal decrease in frequency, go through zero and then increase in frequency again. Again, this is as expected for a DC receiver.

We hope you enjoy your Easy RX kit!

If you have any questions, or experience problems with your kit, please contact us at qrpkits.com@gmail.com and we will be happy to assist you.

Schematic



11

Dave Ross Blog

Electronic design technology development application and New Products

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- Technology Application
- New Products

RSS

Microstrip electric-wave filter and design, making and measuring of the coupled circuit (1

Posted on June 22, 2013 by admin
No commentsLeave a comment

A foreword

Current the intersection of reliance and a lot of tool, designer of microwave, come, produce efficient circuit and system. They want to utilize existing reference data and strong EDA tool and electromagnetic EM Analysis tool, must also combine one's own practical experience to make. The work needs realizing by producing circuit finished in circuit and test finally. This article has described how two microstrip circuit design use all kinds of tool development, mill the control equipment to make fast with the circuit board, then verify the exactness of the design method through measuring.

The design in the example is a directional coupler of 1 to 8GHz for hairpin type electric-wave filter to 4.2GHz of a typical bandwidth 3.7 and one, use Schi ffman sawtooth technology to reduce the size. The hairpin type electric-wave filter uses Agilent ADS1.3 software design and emulation, carry on the level EM analysis with Sonnet Lite software. The coupler has used the variety based on design rule, it is started that it is designed that there is coupler of an extant ladder line form.

Two pieces of circuit are made of Model Protomat C100HF apparatus of LPKF photoelectric Limited Company out, use HP Agilent 8753E network analyzer obtained the measuring result.

2 designs the example 3.7 to 4.2GHz hairpin type electric-wave filters

2.1 Design

This electric-wave filter is designed to obtain a smooth response on bandwidth of 3.7 to 4.2GHz. Insertion loss and echo return loss are superior to 16dB in this frequency band. This electric-wave filter is used in the input end of the low-converter and carried on image rejection. This design chooses a typical hairpin type electric-wave filter, it can meet characteristic and size of the designing requirement.

The electric-wave filter is designed by ADS1.3, Fig. 1 is a result pattern. Certainly, this is a familiar hairpin type structure. The area that the electric-wave filter takes up

is about 500 x 1200 mils 0.5 x 1.2 in. ,Including the hairpin used for keeping invariable logic attribute circulates the required enough area.

图 1， 3. 7 到 4. 2GHz 发夹型滤波器的设计图样， 借助 ADS

Fig. 2 is design and optimization structure in ADS. This topological shape is symmetric in the centre, so it is two-section to design into, a piece of " back-to-back " Structural connection. Because the physical dimension on mathematics is reduced, computation time is reduced greatly.

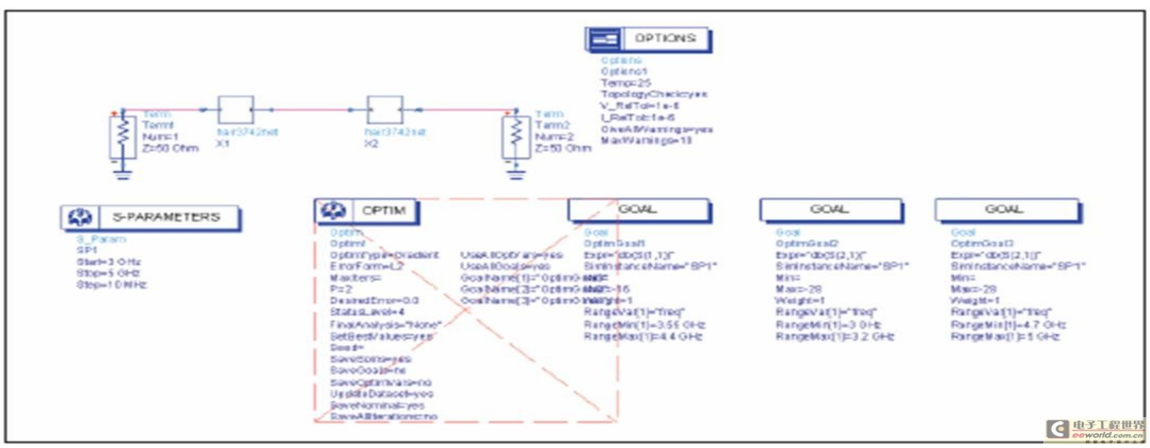


Fig. 2, design and optimization structure in ADS. The electric-wave filter carries on emulation with the graph block of two mirror images, in order to realize symmetrical structure

Set up, come, obtain in the intersection of 3.55 band pass and minimum echo return loss of 16dB in 4.4GHz optimally, and 4.7GHz more than minimum stopband of 28dB decay under 3.2GHz. The frequency domain optimized is 3.0-5.0GHz. The wide-range does not require the result anticipated.

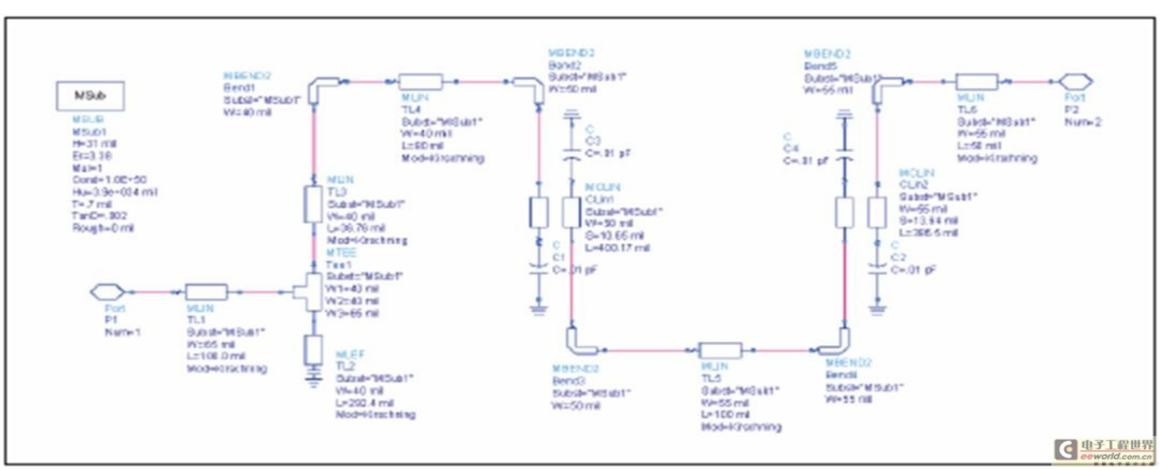


Fig. 3, ADS artificial definition to designing finally. Artificial characteristic and electric-wave filter pattern all come from the data here

Fig. 3 has revealed every one ” Half an electric-wave filter ” ADS design finally,there are and short and convex on including port, microstrip line, T-shape, crooked. Pay attention to the short and convex terminal 0.1pF electric capacity, prove that has an end effect the electric capacity of edge . Fig. 1 one has their display too.

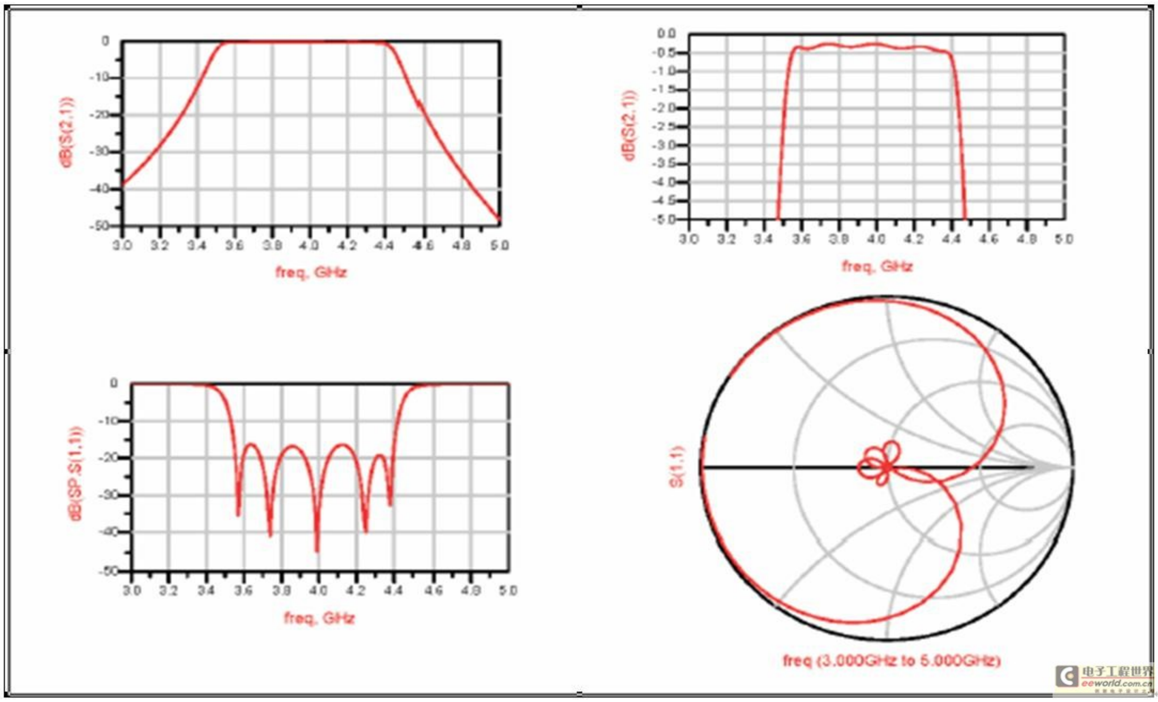


Fig. 4, simulation result.

a Respond to in the whole journey; b Passband response and insertion loss; c Echo return loss; d Smith impedance diagram

The characteristic that is modelling of Fig. 4 reveals. Including band pass, stopband characteristic, echo return loss result and resistant Smith picture of I/O. These charts explain the design criteria that ADS model meets the electric-wave filter.

2.2 EM analysis

Fig. 5 is the detail of the electric-wave filter size. Sonnet Lite level electromagnetic field software that the data designed use Sonnet software company carries on circuit analysis.

A foreword

Current the intersection of reliance and a lot of tool, designer of microwave, come, produce efficient circuit and system. They want to utilize existing reference data and strong EDA tool and electromagnetic EM Analysis tool, must also combine one’s own practical experience to make. The work needs realizing by producing circuit finished in circuit and test finally. This article has described how two microstrip circuit design use all kinds of tool development, mill the control equipment to make fast with the circuit board, then verify the exactness of the design method through measuring.

The design in the example is a directional coupler of 1 to 8GHz for hairpin type electric-wave filter to 4.2GHz of a typical bandwidth 3.7 and one, use Schi ffman sawtooth technology to reduce the size. The hairpin type

electric-wave filter uses Agilent ADS1.3 software design and emulation, carry on the level EM analysis with Sonnet Lite software. The coupler has used the variety based on design rule, it is started that it is designed that there is coupler of an extant ladder line form.

Two pieces of circuit are made of Model Protomat C100HF apparatus of LPKF photoelectric Limited Company out, use HP Agilent 8753E network analyzer obtained the measuring result.

2 designs the example 3.7 to 4.2GHz hairpin type electric-wave filters

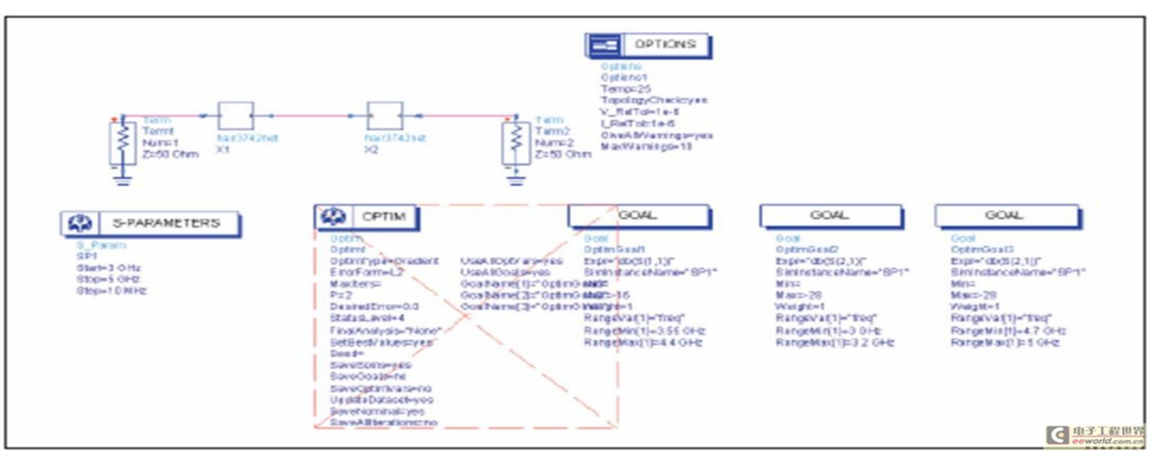
2.1 Design

This electric-wave filter is designed to obtain a smooth response on bandwidth of 3.7 to 4.2GHz. Insertion loss and echo return loss are superior to 16dB in this frequency band. This electric-wave filter is used in the input end of the low-converter and carried on image rejection. This design chooses a typical hairpin type electric-wave filter, it can meet characteristic and size of the designing requirement.

The electric-wave filter is designed by ADS1.3, Fig. 1 is a result pattern. Certainly, this is a familiar hairpin type structure. The area that the electric-wave filter takes up is about 500 x 1200 mils 0.5 x 1.2 in. ,Including the hairpin used for keeping invariable logic attribute circulates the required enough area.

图 1，3.7 到 4.2GHz 发夹型滤波器的设计图样，借助 ADS

Fig. 2 is design and optimization structure in ADS. This topological shape is symmetric in the centre, so it is two-section to design into, a piece of ” back-to-back ” Structural connection. Because the physical dimension on mathematics is reduced, computation time is reduced greatly.



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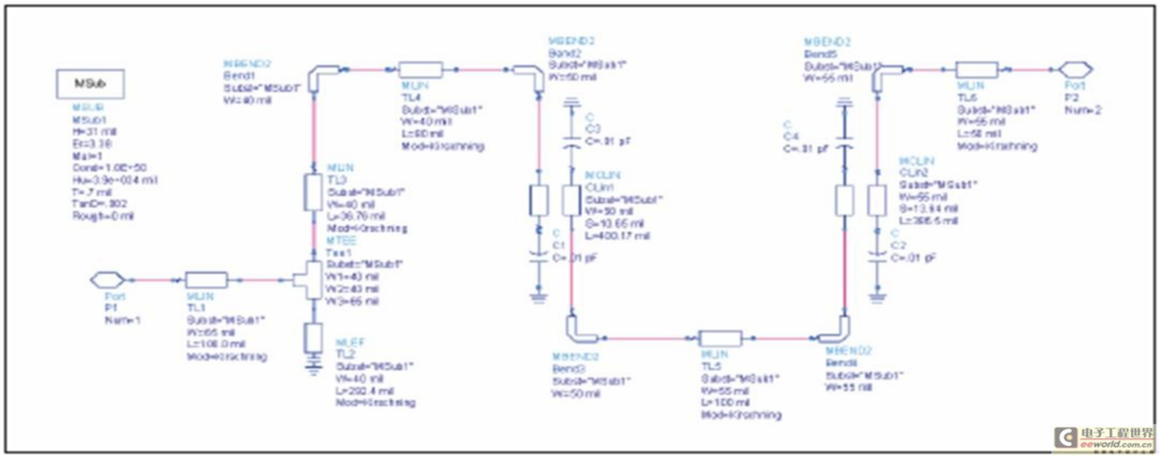

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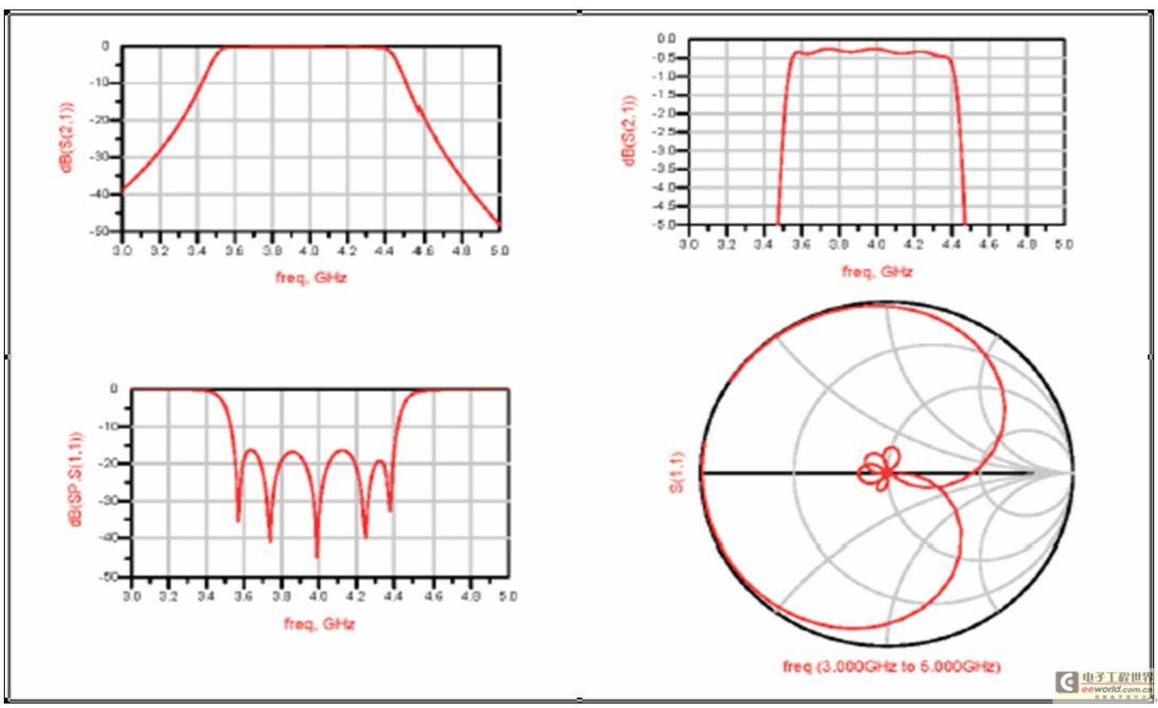

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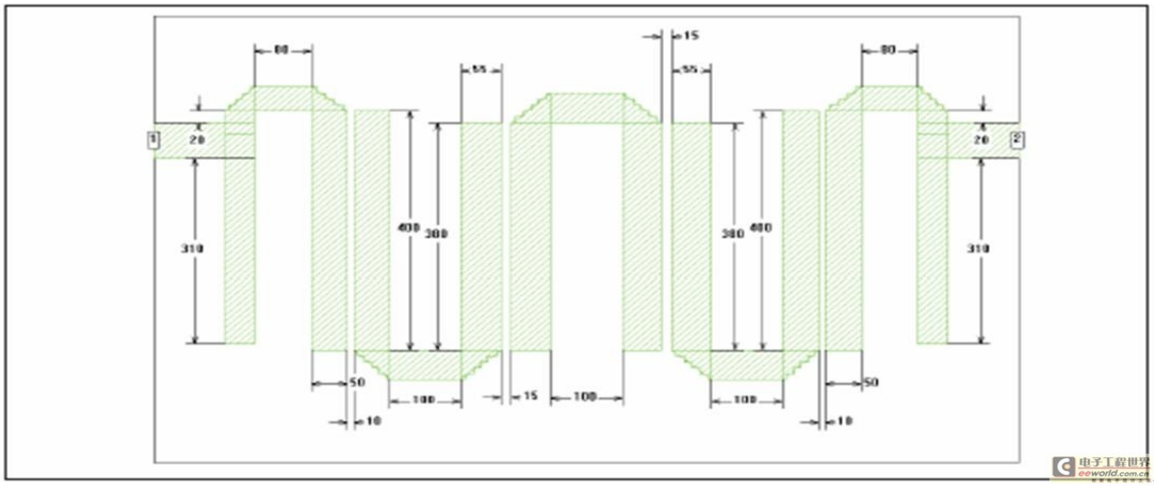


Fig. 5, the detailed size of the electric-wave filter.

Fig. 6 is EM analysis result. The more anticipated than ADS response of the band pass is a little narrower slightly, but if the circuit characteristic that is produced out meets analysis, will cover bandwidth of 3.7 to 4.2GHz. It is very close to ADS model that the passband is smooth. Response of echo return loss in coherent to pull to slightly worse than ADS artificial symmetry. But still can keep 16dB being or better.

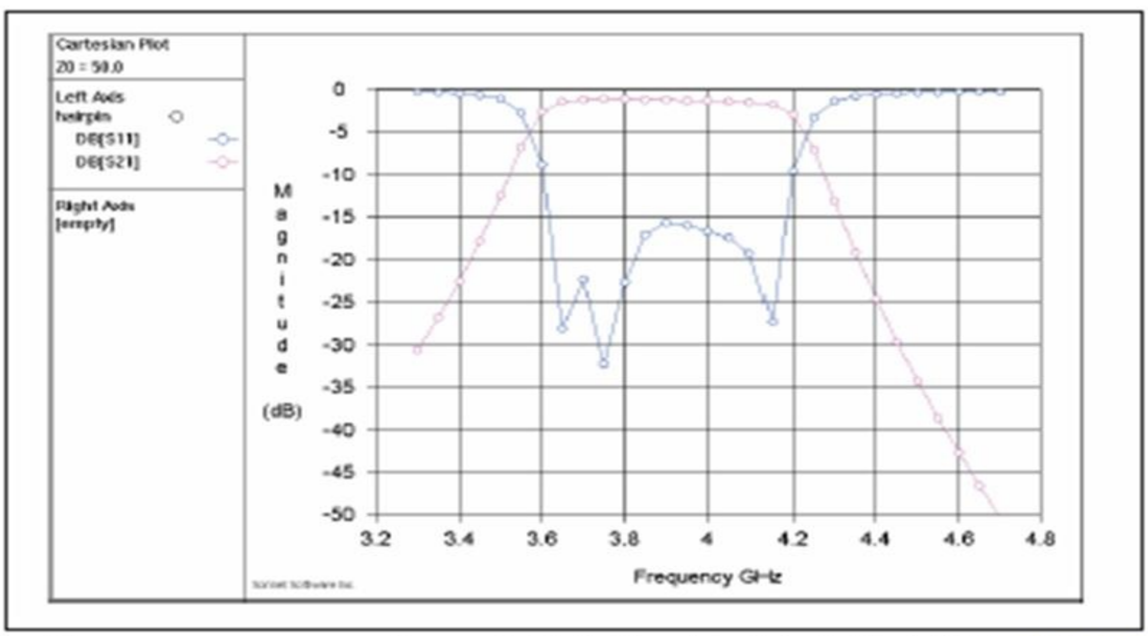


图 6，Sonnet Lite 的 EM 分析结果。显示响应满足设计要求

2.3 Produce a test electric-wave filter

In order to compare the hairpin type electric-wave filter design model and characteristic of the realistic duplicate, will carve the manufacture machine and produce a test electric-wave filter on the typical microwave

plaque together with the circuit board soon. use the Model Protomat C100HF apparatus of LPKF photoelectric Limited Company, see one pair of documents

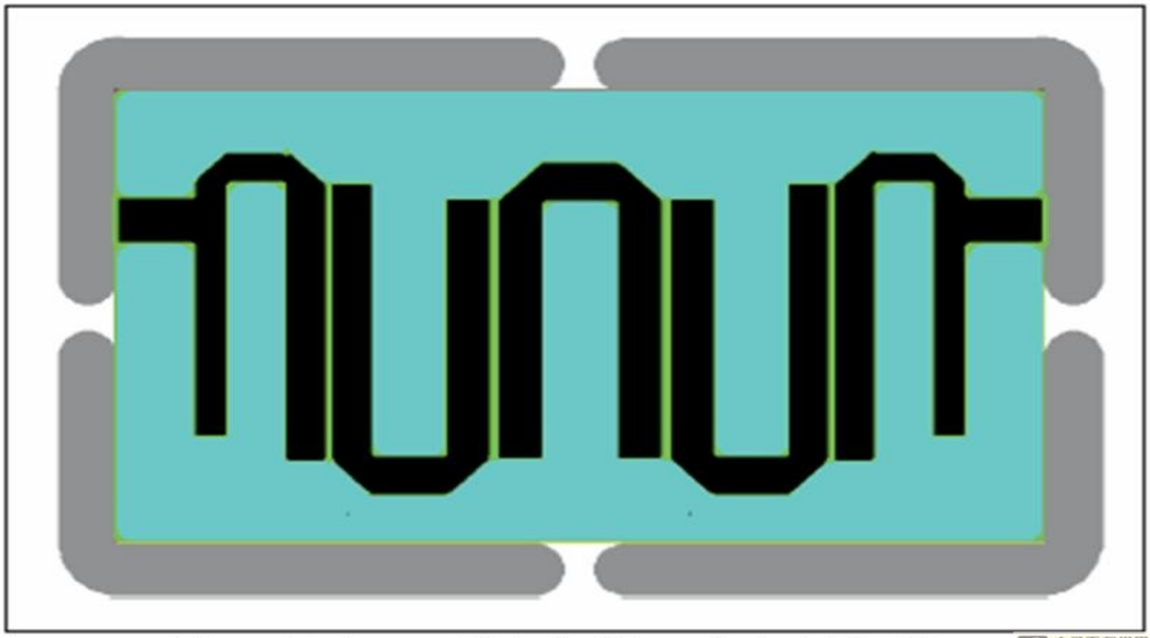


图 7，用于 LPKF 设备铣制加工的电路板图样

Use the intersection of design and the intersection of pattern and data of ADS ' Fig. 1 Produce and carve the essential drive file of the manufacture machine. The size of the figure is introduced into LPKF software by ADS directly. Fig. 7 is the making pattern of the circuit board.

2.4 Test the characteristic

The circuit board is according to designing the milling of pattern to come out, after installing the interface unit, via HP 8753E network analyzer test. Fig. 8 is the characteristic S21 of the electric-wave filter sample circuit board And echo return loss S11 ,Every small dose represents 5dB, has revealed in the whole band passes and characteristic states in the stopband in the chart, reach the most low – 45dB.

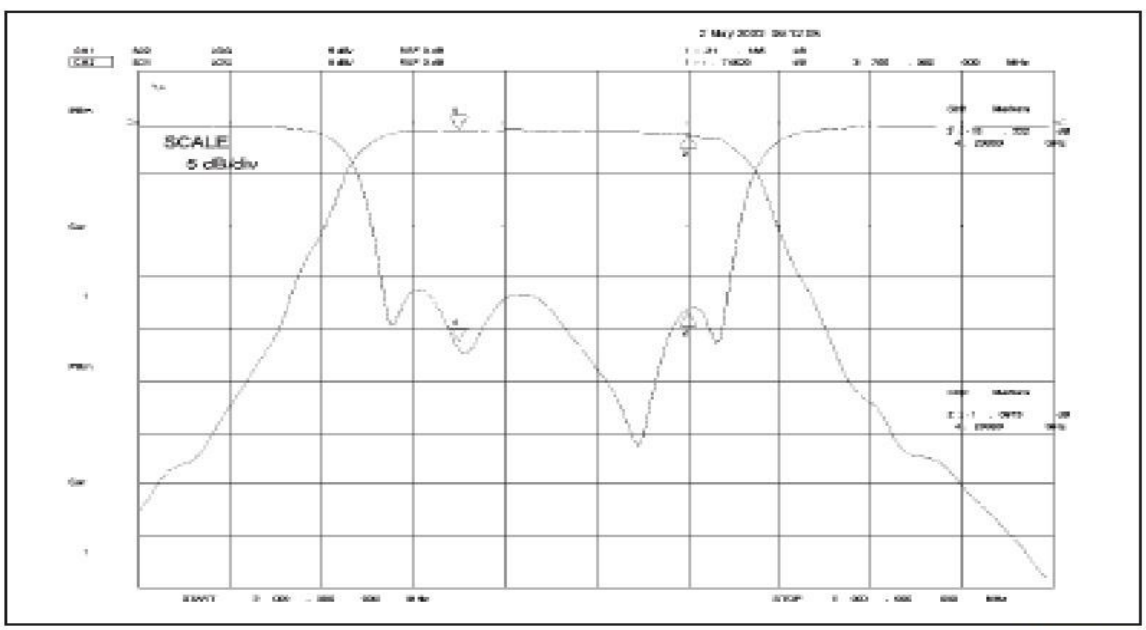


图 8，滤波器样品板的通带和回波损耗的测量特性图

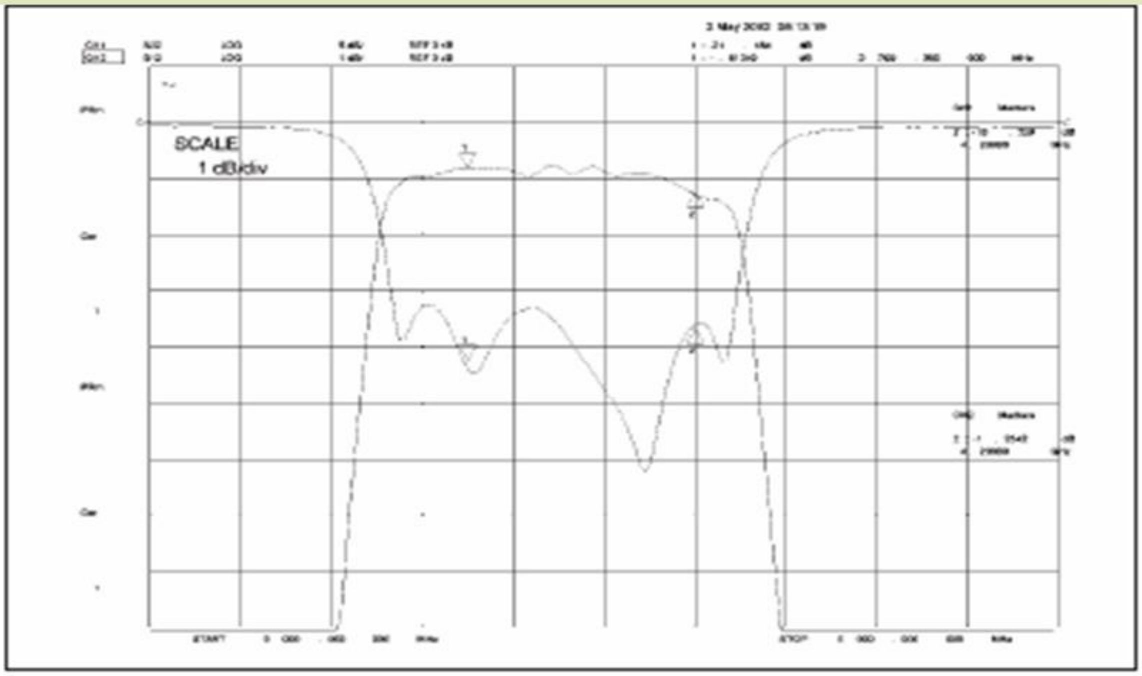


图 9，与图 8 一样，但分辨率为每小格 1dB，以获得更详细

9 Fig. the same as Fig. 8, but band pass come, reveal band pass to be smooth with every light doses of 1dB. Echo return loss is still with every little dose of 5dB display.

Test reveals it is very identical with the model. Band pass narrow a little than a ADS anticipated one, analyze quantity instructed to be a little less than Sonnet Lite. Three kinds of model ways and measurement all point out the insertion loss and smooth unanimity that have of band pass.

Though figures of the echo return loss are different to some extent in these three kinds of models and measured datas, but every one has guaranteed the index of anticipated 16dB, has shown obviously it is due and " bow-shaped " that a multipolar electric-wave filter responds to expecting .
3 designs the example A ladder line directional coupler that size simplifies

3.1 Design

Our another circuit to be investigated uses technological development of the experience. We want to study to adopt Schiffman technology to reduce the circuit size method. This kind of technology is to reduce the mechanical size in order to meet required electric size with a kind of sawtooth pattern.

Start some and choose an existing ladder line coupler to 8GHz, is designed by Paul Daughenbaugh of CAP Wireless Company. This design is converted to and carve the pattern of the manufacture machine for manufacturation, such as Fig. 10. This picture has revealed another kind of edition of the coupler actually, but shown this kind of technology clearly.

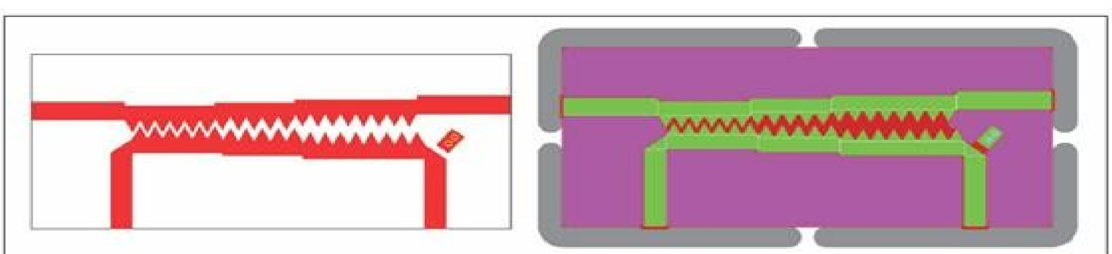


图 10，基本图样（左）和制作模板（右），显示了 Schiffman 小尺寸定向耦合器所用的技术

Get layout work of the new coupler from the coupler design of straight section by a experience method, according to the following rule:

Close interval section – -It is the same to make the length of straightway of total length and this section of the sawtooth route into. Have cut down by nearly half of this part of length like this. In the straightway " The interlocking " Tooth among keep still to space,can with sawtooth by present by ways rectangular to last magnitudes interstitial.

Wide interval section – -Third sections of line intervals, according to the middle height indicator of teeth

Calculate. Under this wide interval, suppose that can carry on coupling according to the field of average interval, but not carry on coupling along the route of the first passage. Likewise, the size of this segment cuts down less. In order to simplify, has adopted it with in fact some uniform length of tangential path.

Interlude – -Interval and size of the interlude cut down and obtain by calculating according to first passage and the third section of geometric average.

This " best supposition " Way essential,because can not with software tools Off-The-Shelf last the structure. It is too complicated to analyze with Sonnet Lite, other analysis tools can't be used at all.

3.2 Coupler characteristic

After the coupler is made of scribing the machine of LPKF out, should assess the coupling grade and in the inner directivity of frequency band of 1 to 8GHz. The coupling port transmission signal in Fig. 11 is a sleek line. The horizon of the middle part of chart is – 18dB, small every dose of the mesh is 2dB. Couple to within the range of metric frequency – 19dB 1.5dB. In the the same picture, echo return loss that input draw with every light doses of 5dB, it counts second stripline from crest to be whether 0dB consult. Place echo return loss maximum of low frequency the most, it is 16dB.

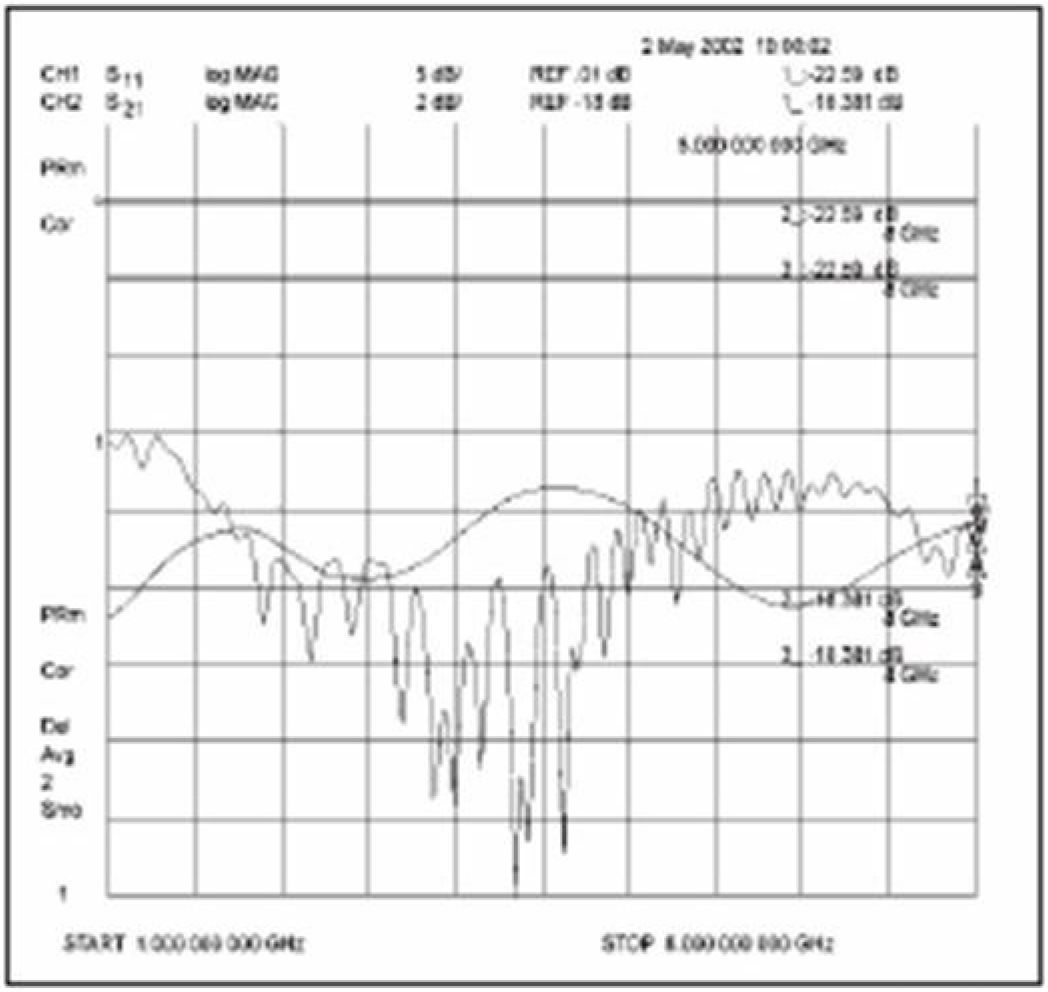


图 11，耦合端口传输信号和输入回

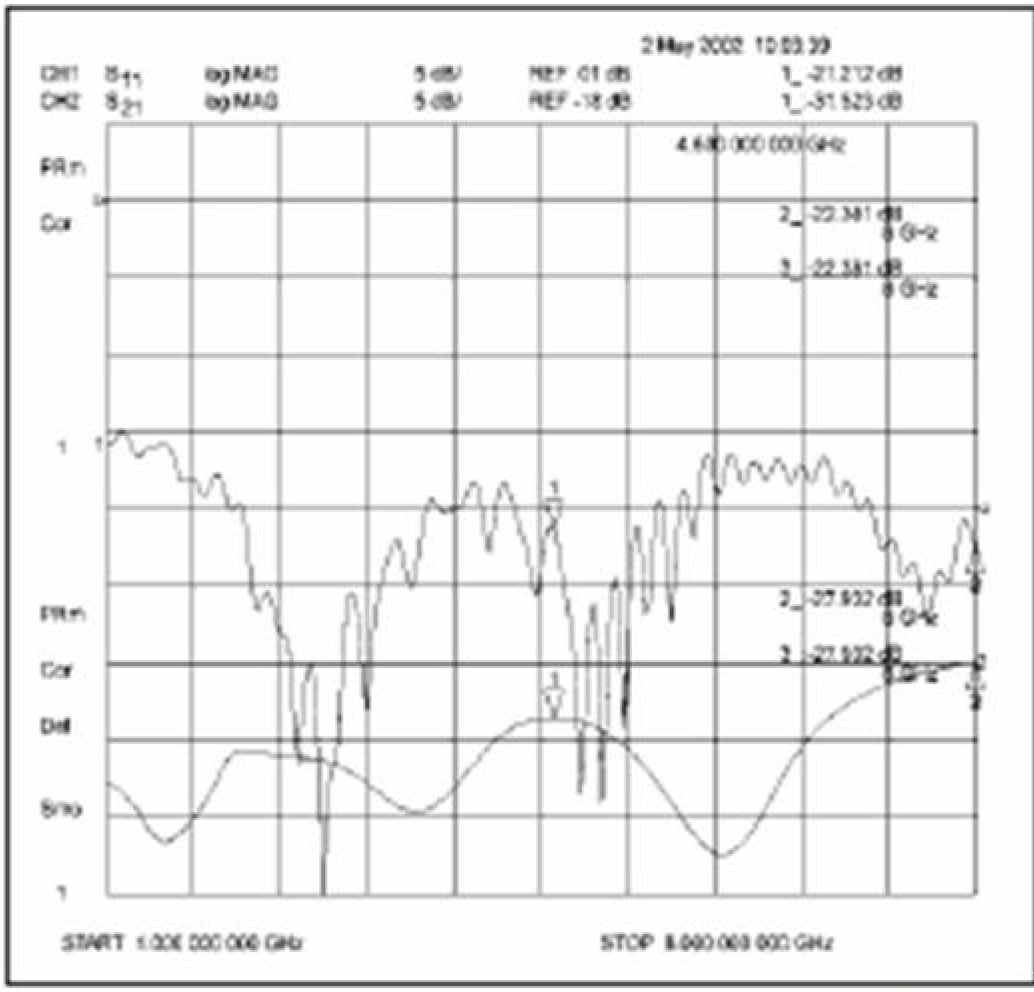


图 12，反向耦合和输入端口回波

Backhand coupling is drawn and pursued in Fig. 12, including output port echo return loss. Every small dose is 5dB in two pictures. As to backcoupling, line of middle part – 18dB consults, it is better to couple to – 28dB or, lie in the high-frequency end. It is drawn with the uniform method of echo return loss of input in Fig. 11 that the output port echo return loss is adopted, the worst in 1GHz place characteristic too, it is 16dB.

Whole journey inner the directivity ‘ Forward coupling deducts backcoupling It is 10dB, lie in pole high side of the wave band. The design object is higher than 10dB, reaching 12dB can reserve the extra space. Can reserve this excess in the great subband definitely, we are regarded as an extremely good result of original test.
Fig. 13 is the insertion loss, under 1GHz is 0.25dB, it is 0.57dB that 6GHz place is the worst. The change of the insertion loss has 0.33dB only in the whole frequency band of 1 to 8GHz.

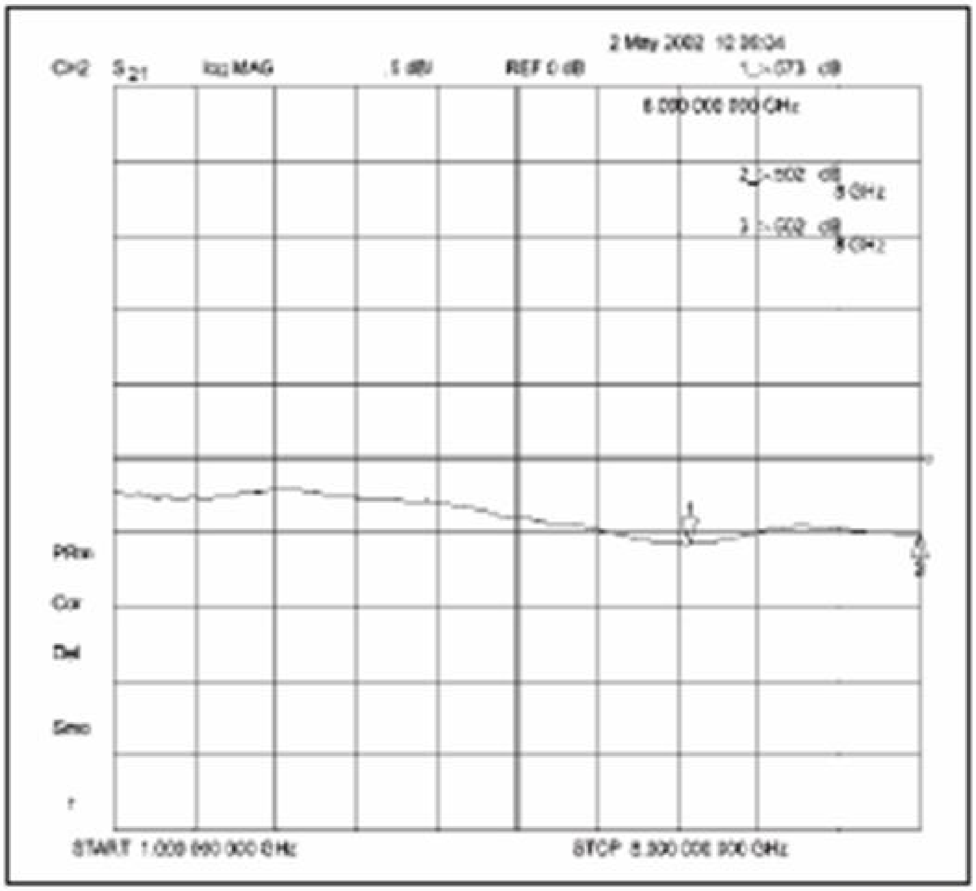


图 13，插入损耗，垂直方向分辨率为每小格0.5dB

4 microstrip circuit boards completed

This kind makes sample circuit board method fast to make the fabrication process change according to designated design. As to direct coupler, want, reach anticipated characteristic, we prepare several repeated design perhaps. Fortunately ‘ Also the rational supposition on the basis of experience ,The first test gets an intact coupler.

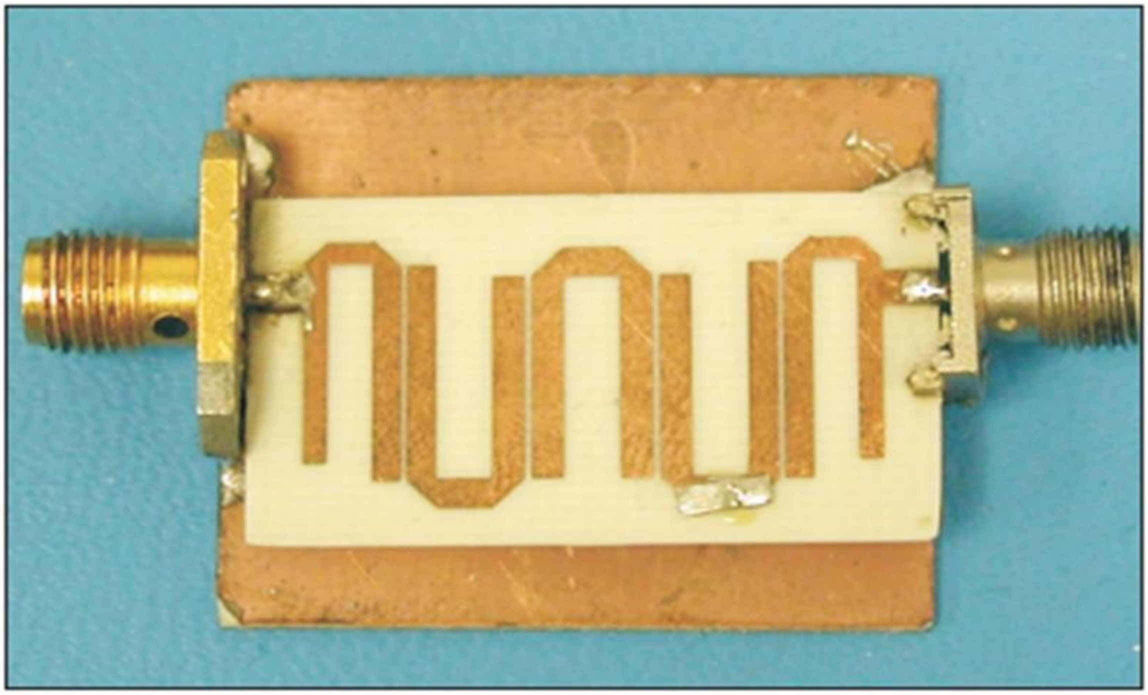


图 14，3.7 到 4.2GHz 发夹型滤波器的样品板照片

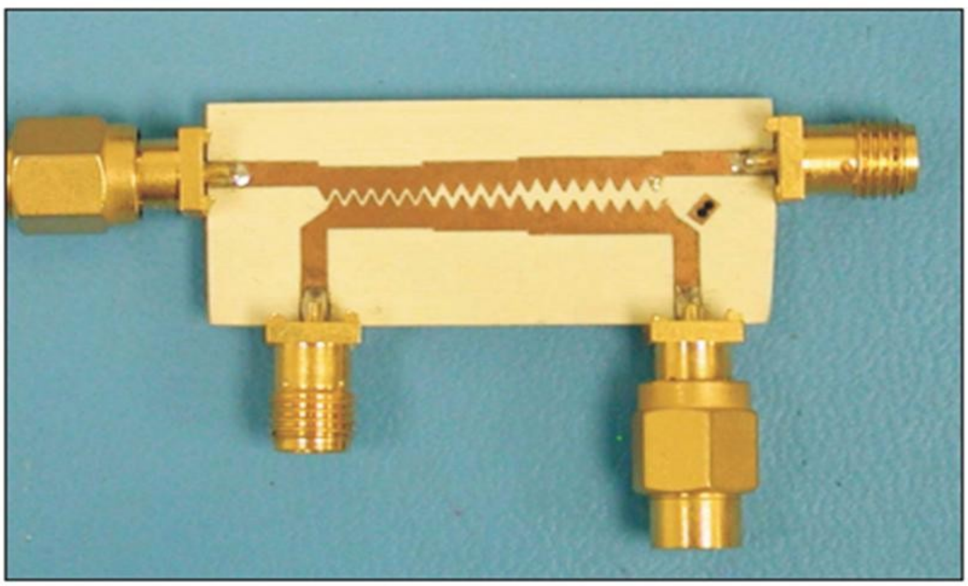


图 15，使用 Schiffman（或称锯齿线）技术，1 到 8GHz 的宽频带耦合器的照片

The photo in Fig. 14 and Fig. 15 has shown the good circuit board of milling, and the interface unit used for testing. The hairpin type coupler in Fig. 14 even has a small pieces that is welded on a microstrip collinear segment interval among them. This is caused by a little fault of the design documentation, cause in the milling circuit board, that interval comes out the milling obviously.

The coupler is designed and can also be revised in order to improve the echo return loss of low-end or make coupling respond to planarization. And if let the traditional circuit board factory of outside make, such a small change might not be taken notice of. Because of the requirement for the regulation in environment protecting mode, complexity and cost of the chemicals processing procedure increase notably, especially in California, most companies no longer keep the indoor circuit board and etch the laboratory.
In order to produce these electric-wave filters and coupler circuit, we have synthesized a lot of designers' experience, materials data, advanced circuit theory emulation, EM analyzing and final making and measurement means. The whole success that designed uses different design resources, design, analyze the realization to the microstrip circuit from the theory. This course of the completion that can be fast, tools – -It is indispensable that

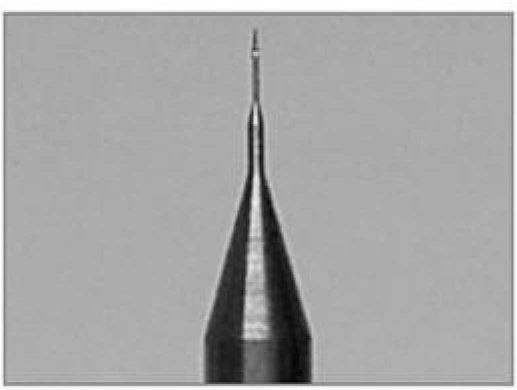
the circuit board carves the manufacture machine.

5 uses the circuit board to carve the characteristic made the sample circuit board of the manufacture machine

CAP Wireless whom Company use carve control equipment, come from the intersection of LPKF and photoelectric Co., Ltd. ‘ www.lpk.com Protomat C100HF type carve cock. This apparatus can be suitable for 13.5×8 inches 340×200 mm Circuit board. Circuit board, also can milling aluminium or the components of copper,or whether it last cast-on-copper flake.

The motor operates the speed to transfer from 10,000 to 100,000 to the software adjustably. The typical meticulous milling cutter described in this article is the end milling cutter of one 10 mils, the variation range of the diameter is 0.2 mils in processing.

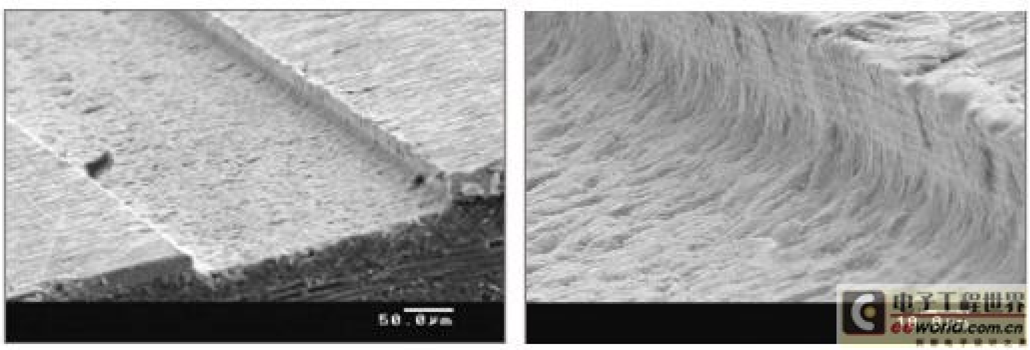
The location accuracy of this machine is for guaranteeing the accuracy of X, Y axial size accuracy and penetration depth is very important. The machine must cut the whole copper foil layer reliably, cut away minimum amount substrate at the same time.



The milling process the recent photograph of the head in photo above. C100HF adopts the dynamic Z axis to position, the coaxial deep stop of processing keeps the milling depth. The depth of penetrating the substrate is generally 0.2 mil 5 micron . The movement range of the Z axis is 14 mm 0.55 in . It is sensory that the air bearing has offered the accurate but non-contact type surface, suitable for processing on soft or flexible planking and surface responsive material.

The definition of this machine is 0.3125 mil 5 micron . X-Y location accuracy smaller than 0.2 mil 5 micron .

The following electron micrograph has revealed the milling orbit under different magnification, have marked the proportion with 50 micron and 10 micron separately.



In 40 mm/sec 1.575 in Under the migration velocity, meticulous milling and large-area shell copper finish high-efficient equally. If necessary, can finish design and test of several times within one day. Under some situations, this machine can be ordering the mould and producing the respect in batches to substitute the production of the traditional circuit board small.

Other models of LPKF Company such as ProtoMat H100, H60,etc. have ability to process microwave circuit board too, advanced model these possess automation, change, location accuracy high, the intersection of migration velocity and swift characteristic, can meet the higher canonial making demand, and can satisfy the production of certain batch. Demand that have met the laboratory, research institute and the Hi-Tech company makes the circuit board by oneself.

Categories: Technology Application | Tags: communicati test, Coupled circuit, coupler, Microstrip electric-wave filter, Wireless RF
Permalink: Microstrip electric-wave filter and design, making and measuring of the coupled circuit (1
On the basis of the image identification system design of SPCA563B chip
SE battery implement method gathered

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My First Amplified Radio Project

based on the Armstrong regenerative principle

with detailed notes on what lead up to building it

A comprehensive story containing historical, educational, technical and biographical elements & my opinions
by
John Fuhring

Please read this Note:

This story is NOT about the history and theory behind the first practical radio.

If you are looking for diagrams and an essay that describes how the first practical radio receivers worked, you will find all that in my
Coherer Detector essay.

I apologize that my choice of works for the title of this webpage has caused so much confusion.

This is the story of how I came to build my first vacuum tube radio back in 1958 when I was in the 8th grade. Also please note that **this story is not meant to be a construction project**, but only a story. The following story is an E-book that you can read for free and I hope you are entertained by the story. If you take the time to read my story, I guarantee that you will learn some history and some electronics too.

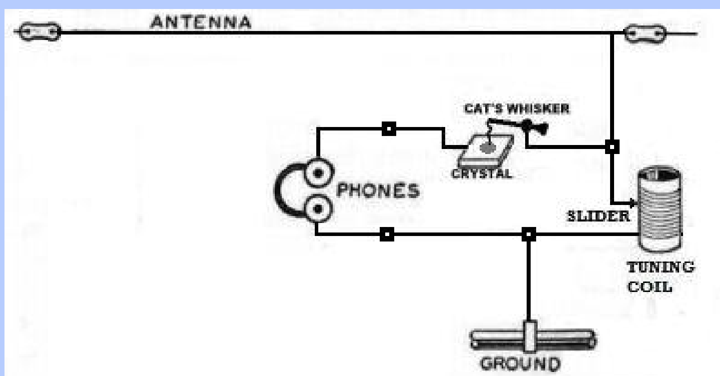
If you have come to this page wanting to build a simple, easy to build, but great performing little radio, I urge you to consider my Armstrong "Crystal" Radio project. If you would like to build a good looking version of that same radio, consider my Geezerola Senior Radio.

Otherwise, please look over the story of my first vacuum tube radio. Even if you aren't much of a reader, please look over the pictures and see if there isn't something that you will find interesting to look at and maybe read about. It won't cost you anything and you won't have to look at any advertisements.

My introduction to the magic of radio science

I can remember exactly when my interest in radio technology began. In 1955, when I was turning 10 years old, my wonderful aunt Helen sent me a birthday present. Inside the box was this outlandish collection of wire & other hardware including a rock crystal, a small "cat's whisker" mechanism, a wooden coil form, a Bakelite chassis for mounting everything and a set of rather nice headphones (that I still use). It also contained a sheet of instructions on how to wind the coil, how to mount everything in the chassis and how to wire all the parts together.

My first crystal radio in its Bakelite chassis.
I was searching the Internet for old crystal radio kits and
good lord, there was a picture of my radio just as I remembered it.



Schematic diagram of my first crystal radio.
Actually, this is an extremely poorly performing design.
Lately I've built **a tiny crystal radio that is far superior.**

The crystal detector was a vast improvement over the **coherer detector**, but it loaded the tuning circuit by having to drive the headphones directly and it offered no amplification. AM radio stations transmit a lot of power and the antenna picks up enough of this power to be heard in the headphones enabling you to hear sounds from your crystal radio. Now compared to a regenerative radio, crystal radios have both poor selectivity and poor sensitivity, but they worked well enough that they provided world-wide communications, were used by the Armies of the Great War and when the military surplus crystal radios hit the market at the end of that war, they started the Radio Age.

In addition to all the parts, the box included printed instructions on how to string up an antenna wire in a tree and how to establish a ground using a steam radiator or water pipe. In addition to all that, there was an illustration of how radio waves travel from a station and how these waves are captured by the antenna as they pass by. The sheet went on to explain how these waves are turned into electrical currents by the antenna. It told

me that the different radio stations are then separated from each other by the tuning coil. Finally, there was an explanation of how a radio current, that is impossible to hear, is turned into electrical sound waves by the crystal and cat's whisker and then how those electrical waves cause the electromagnet inside the headphone to make the headphone's iron diaphragms vibrate and it was these vibrations that made the sound. I don't know where or how I knew some of this stuff, but I had already been exposed to bits and pieces of electrical theory and electromagnetism, so putting it all together this way made sense to me.

For all this explanation, I still couldn't understand how anybody could call this collection of wire, rocks and other junk a radio? Naturally, I was familiar with radios and as all people did back then, I avidly listened to news, comedy, music, drama and adventure programs that filled the AM radio waves. But, but, BUT, all "real" radios had these glass tubes in them, tubes that you could see the insides glowing red hot if you looked around the back. What is more, I knew that radios worked on electricity and they had to be plugged into a wall socket or no sound would come out.

Now, here in this box were the parts of something called a "crystal radio," but there were no tubes, no batteries and no power cord. Looking at all these inert parts - wire, screws, wood, Bakelite plastic and a piece of rock - I was extremely skeptical that anything so simple could possibly be used to hear radio programs. My mom (born in 1909) assured me that when she was a girl, many people in her town in rural Pennsylvania made these little radios and with them they would spend their evening hours listening to the big stations in Pittsburgh and Albany. My mom knew everything, so I put aside my skepticism and decided to build this thing.

My first attempted to build the kit and get it to work was a failure because I didn't understand the importance of winding the tuning coil neatly and I got some of the interconnecting wiring wrong in my haste to put it all together. When I complained that couldn't hear anything, my mother pointed out that my workmanship was really poor and of course it wouldn't work looking that sloppy. It was obvious that she was right, so I got out the sheet and this time I put it together according to the diagram. I rewound the coil, but this time all the turns were regular so that the antenna slider could now move smoothly from side to side. As per the instructions, I took some sand paper and carefully sanded the varnish off the top of the coil so the slider would make contact with the wires. I took the interconnecting wiring out and then carefully rewired it exactly the the way the diagram showed. When I was done, I was pleased to see that my radio now matched the instruction sheet perfectly. The lessons in craftsmanship that I gained from building this radio were good and early lessons that have served me well since. If you want something to work, you must build (or repair) it right.

Confident in my workmanship, but still feeling skeptical, I placed my radio on a little wooden shelf above my bedroom's radiator. I then connected the end of the antenna wire (that I had placed up in a nearby tree per instructions) to the little "antenna" input of the Bakelite chassis. My bedroom's steam radiator had a bright chrome-plated vent valve, so I connected a wire from the radio's "ground" connection to it. I could almost hear a drum roll as I put on my headphones. Silence -- I could hear nothing in my headphones -- so I moved the slider from one side to the other, but still silence.

At this point, I learned another principle that has served me well all my life and it is just this: "**when all else fails, read the instructions**." The instructions said that I had to find a "hot spot" on the crystal by moving the tip of the "cat's whisker" over the crystal until I could hear sound. Well OK, I made a connection between the tip of the whisker and the surface of the crystal and then tried moving the slider again. I was absolutely stunned when I could hear sound in my headphones and the sound got louder as I moved the cat's whisker and found a better "hot spot" on the crystal.

How could this be possible?? Here I was, hearing voices and music coming out of mere wires and doing so with no tubes, batteries or house current to supply electrical power, but that was impossible. I mean, even back then I knew that Nature does not give you something for nothing, so where was the power to create these sounds coming from? I was extremely impressed and although it seemed like a miracle, I knew it wasn't supernatural, but rather it was a "miracle of science" and so I wanted to know all the mysteries behind how this stuff worked.

Because the radio was made up of ordinary things, I felt confident that I would eventually understand how all these parts combined to do what seemed to be magical things. The tuning coil I made up myself out of ordinary copper wire and it was wound on an ordinary piece of wood, the cat's whisker mechanism was made of ordinary pieces of metal and the crystal was just a shiny piece of rock. When I unscrewed the cap on the headphone, I could see the iron diaphragm and the coil of the electromagnet inside. Although it seemed like magic, it wasn't magic and I was sure that it wasn't beyond my ability to understand how it all worked. It was immensely

pleasing to see (and hear) how I could take ordinary things and make them do something so wonderful. This was the beginning of a life long fascination with radio and electronics that has continued (off and on) to this day.

I made several improvements to my original crystal set including replacing the big "cats whisker" with a bead of glass that had a tiny crystal with a tiny cats whisker inside, but that actually worked a whole lot better than even the best big cat's whisker. Looking back, I wonder that I was able to keep my interested in radios alive during this period because neither my parents or teachers encouraged me in this and none of my friends had the slightest idea how radios worked, or shared my interest in anything so "square" (or "nerdy," as we'd say today). My parents and teachers considered all these wires and batteries as a pernicious distraction from my otherwise neglected academic work and prejudicial to my social development. Perhaps they were right, but a nerd will be a nerd, a Dilbert will be a Dilbert, there is no other way we can be, and, as it turned out, my hobbies did more for me in my later life than any of the "book learning" that my betters forced on me. So, I continued to want to know more about radios, wires and gadgets and to teach myself what I could about all that stuff.

I'd like to take a brief digression here and I hope you don't mind. I found out later that making and listening to these simple radios was a craze back when my mother was a girl and their wide-spread use starting in the early 1920s was largely responsible for getting early broadcasting started. I don't think it is a bit of an exaggeration to say that these were the I-pods of my mom's generation and it was these simple devices that even poor people could afford that started engineers and scientists looking for better and better ways to receive radio signals. This untiring search has resulted in the world of electronic communication and entertainment we have today.

More crystal radios

By 1957 we were living on the hospital side of Camp Pendleton Marine Base and I was in the 7th grade. By this time, the crystal radio bug had really hit me and I experimented with improved crystal detectors. I discovered that the little glass 1N34 diodes worked better than any cat's whisker and the Marine Corps hobby shop sold them. While playing and experimenting with crystal sets and diodes, I heard about these little things called transistors that were just becoming available. My folks knew what interested me, so they bought me another little crystal set for Christmas, but this one had a one transistor audio amplifier in it and it was so cool looking. This radio worked really well and it was the center piece of a radio corner that I set up in a little "fort" that some of us kids built out of wooden crates and large boxes that we salvaged from the Marine Corps' military dump. Unfortunately, there were no trees around, so my very poor antenna system consisted of military field telephone wire laid along the ground and in the sagebrush. It so happened that the tuning of this little radio was so broad, I could hear some of the military shortwave broadcasts the Marines made while on maneuvers on other parts of Camp Pendleton. I just loved it.

My Remco crystal radio with a transistor amplifier.

Well, in 1957, transistors were still mostly curiosities and very, very expensive. Transistors were also tiny and their workings were hard to understand. At that time in history, the next step for a boy learning about electronics would naturally involve electron tubes (sometimes known as vacuum tubes, valves or simply as tubes).

Electron tubes

I really began to learn something about radios and how amplifiers worked when, about age 13, I built the one tube regenerative receiver I will shortly describe. Children of my generation were quite familiar with tubes, we all knew that tubes were what made radios work and that sometimes tubes "burned out" and had to be replaced. Yes, we all knew about tubes, but I wanted to know what all those things inside were and what made those tubes work.

The wonderful thing about tubes is that they are built to a macroscopic scale. When I was a kid, I would look long and deeply into tubes, let my imagination soar and see a fantastic, glittering, futuristic city inside that glass envelope. I could look inside the glass and into that vacuum filled Electropolis and identify each glittering element. I could break open old tubes to examine their contents under a magnifying glass and see that they were nothing more than thin strips of metal or wire. Even a kid like me could see and identify the 'cathode,' the 'heater' wires, the wire spiral that made up the 'grid ' and the thin metal 'plate' (or anode) that encased everything. By seeing all these parts and holding them in my hand, I could imagine electrons "boiling" off the hot negative cathode. I could imagine how they would be attracted to and picked up by the positively charged plate (anode) and how that flow could be modified by tiny voltages on the grid wires. It was an easy step imagining how tiny voltages appearing on the grid would be amplified into large plate currents that would run the powerful electromagnets of a speaker.

A visit to the magical city of Electropolis

Speaking for my fellow nerds, I will say that there are few precious jewels that look so beautiful as a big, old fashioned, glass vacuum tube containing within it a glittering Electropolis. These futuristic looking "cities in a bottle" were manufactured up to 75 years ago using technologies that, to this day, most of us don't understand and have no experience with, but nevertheless, they are existing unchanged and unchangeable, preserved forever behind a thin, transparent glass capsule that preserves their nearly perfect vacuum.

Within any one of these tubes, between the glittering elements, across the ultimate emptiness of the vacuum inside, flow invisible and complex streams of electrons that no living creature may see. The passage of electrons are invisible, but fortunately our mind's eye has the power to "see" things our mortal eyes can't see. With a real

sense of awe, I sense the truth that tiny, almost massless, subatomic charged particles people call electrons are making their highly regulated journey through this vacuum at nearly the speed of light.

In school and through our textbooks, you and I were taught - and we can readily believe - that this "electric fluid," this plasma of charged particles, is moving under the influence of a high voltage electric field, but that the movement is made possible only because the cathode is red hot. Again, our mind's eye "sees" a cloud of electrons that has been "boiled off" the metallic cathode through that wondrous process called the "Thermionic Effect." What is more, we know that this flow of electrons between a tube's elements can be and is precisely regulated by tiny electric charges that make their way to that spiral of gleaming wire called the grid.

We know that all this scientific magic is true because we built the radio ourselves, we connected our high voltage 'B' battery to the anode and cathode circuits and we are using current from our 'A' battery to heat the cathode red hot and make it boil off electrons. We know that this isn't *"just a theory"* constructed by people learned only in magical and superstitious thinking but is instead a Scientific Theory constructed by people highly learned in the complexities of real world science. Each of us can see into the very heart of the tube and we can hear music and voices in our headphones so we know all this is happening, but you and I can only experience this kind of epiphany to its fullest degree if we have a vacuum filled tube with its glittering Electropolis to stare into.

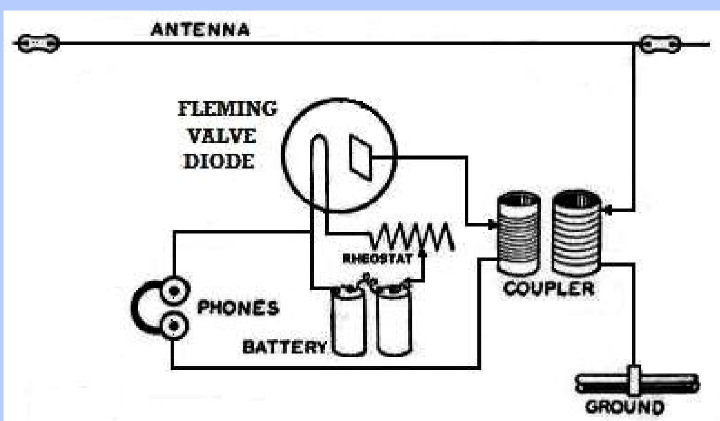
Back home on my side of the glass

As a first lesson, I learned that vacuum tubes operate on that almost forgotten principle called the "Thermionic Effect" that I mentioned above. This principle is so important, I want to say more about it. Way back in the 1880s researchers at the Edison Laboratories in New Jersey (not Edison himself) discovered that some kind of an "electrical fluid" (later found to be electrons) "boiled off" hot filaments, but in a one-way direction (from the cathode to the anode). Later, John Ambrose Fleming used this principle to produce an improved diode tube (the famous Fleming Valve) to detect radio waves. At the time, this was the best detector there was. It was thousands of times more sensitive than the coherer detector in use at the time and it actually worked better than the crystal diode which came a little later. Of course, the crystal detector was much, much cheaper, required no battery, lasts forever, is very rugged and so crystal detectors with their annoying cat's whiskers superseded the Fleming Valve for a long time until it made a comeback in an improved form about 20 years later.

Warm tubes and cold transistors

By the way and this has nothing to do with the present discussion, later on, when I started to experiment with transistors, it was impossible for me to see inside them and so it was much harder for me to imagine "holes" moving through a crystal lattice. The truth is, I've never had a "warm feeling" for transistors and integrated circuits, regardless how marvelous they are. No, but I've always had a kind of affection for tubes.

The first thermionic vacuum tube radios

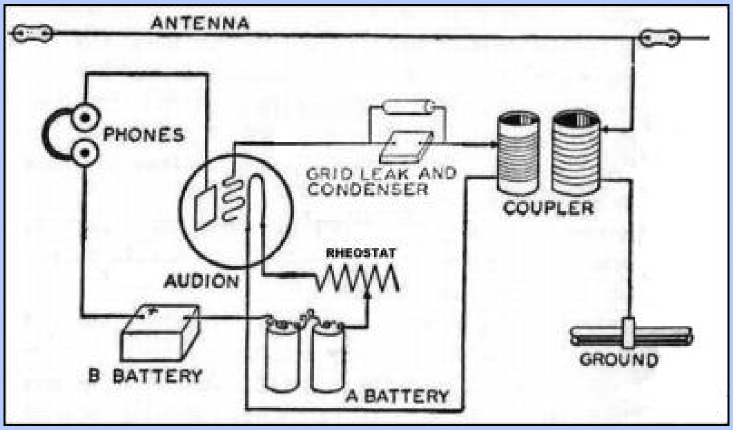


A Fleming Valve Detector Radio.

Very similar to the crystal detector, but generally more sensitive. The Fleming Valve was superior to the crystal detector, but consumed expensive tubes and batteries.

In 1907, Dr. Lee De Forest added a third circuit element to a modified Fleming Valve tube to make a (very expensive and unreliable) crude forerunner of the triode tube, called the Audion. To get around Fleming's

patents, De Forest left a lot of gas in his audion tubes so that they operated in a very poor vacuum. De Forest then claimed that it was positive ion migration that made his tubes work. In 1912, while still an undergraduate in college, a very young Mr. Edwin Armstrong wrote a paper that proved De Forest was completely mistaken regarding the internal operation of the Audion and indeed De Forest really didn't have a clue how his tubes worked.* In hindsight we can say the Audion was a crude device, but it was an important start and it soon evolved into the linear amplifying high vacuum triode tube through the work of other researchers.



An Audion Detector Radio.
A so-called grid rectifier detector.

Note the similarity of this "grid rectifier" radio to the Fleming Valve and crystal radios. Feeding the grid of the audion caused much less loading of the tuning coil so that stations didn't blend together as badly and, most importantly, the signal is amplified so that weak signals can be heard much better. If the Audion tube is adjusted so that it conducts an electric current through it (between the filament and the plate), the strength of which depends on how positive the grid becomes (as the signal wave varies). It doesn't take much change in the tiny voltage on the grid to cause a large change in current flow in the plate circuit, therefore the tube strengthens the signal and in doing so, it produces a varying plate current. The phones are in the circuit between the plate and the battery, so that this current is also flowing through the phones and will be heard as sound.

These radios were used mostly by experimenters, radio amateurs and students. In addition to being very expensive, each Audion was unique - some worked great, others didn't work at all - and just when a guy had spent his last dollar and finally had a tube that really worked well, the darn thing would burn out or just stop working. From what I've read, there was a real love/hate relationship between the Audion and those who experimented with them. For these reasons, the Audion wasn't popular commercially or with the military except that the Navy had some radios that used them. Then came *The Great War* and that put an end to the commercial market for Audions and civilian radio in general until after 1918.

An Audion tube from 1909

A short history of how the Triode evolved from the Audion here in America, traveled to France and then got back to America

Dr. Lee De Forest, searching for ways to improve the Fleming Valve as a radio detector, invented his Audion tube in 1906 and by 1912 he had nice little business making and selling these tubes as radio detectors. His tubes had a lot of gas in them (a "soft" vacuum) so they could not amplify voice or anything that required "linear" amplification. Today they would be called "thyratron" tubes and certainly not triodes. Thyratons can act as radio detectors, oscillators and high power rectifiers and their high speed binary (on or off) switching characteristics made them very useful in the first electronic computers, but nobody would ever use them in a audio circuit requiring linear amplification.

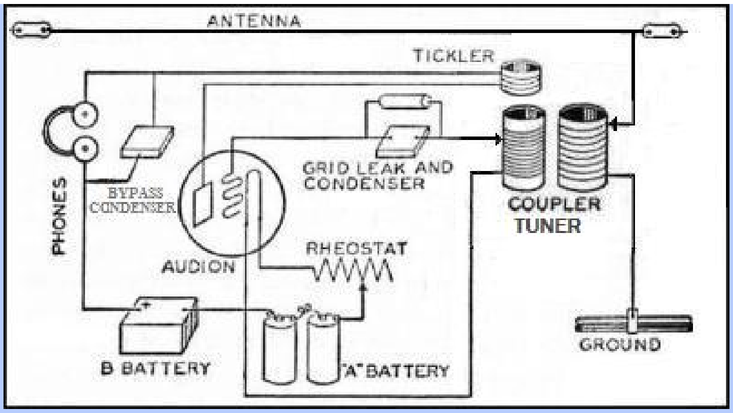
Since they didn't have electronic computers in those days, De Forest was sure that his Audion was good for nothing besides radio detection, so he sold the patent to his tubes to Western Electric for only $50,000, but only under the condition that they would not sell their tubes as radio detectors. Western Electric was eager to buy De Forest's patent because their chief scientist, Dr. Harold Arnold, unlike De Forest, understood the quantum physics that goes on inside these tubes. Dr. Arnold was sure that if he pumped all the gas out of one of these tubes and created a hard vacuum inside, the tube would work wonderfully to amplify telephone signals. Well, he was right, his tubes stopped acting like thyratrons and the first true triode was created. Very soon afterwards, coast to coast telephone calls were possible because of the clean, linear amplification that these new tubes made possible.

A couple of years later, during the summer of 1914 and just before World War One began, Paul Pichon, a scientifically literate Frenchman who was working as an industrial spy for the German Telefunkin company, came to America and was given some of Western Electric's improved tubes to take home. As Pichon was returning to Germany and just as his ship arrived in England, the First World War broke out and the British authorities arrested Pichon. To get out of jail, Pichon tried to give these special tubes to his captors, but the British didn't understand the importance of what the Frenchman had, so he (and his tubes) were sent to France. In France, a panel of top scientists was put together and they experimented with Pichon's tubes. They discovered that these Western Electric tubes would make highly superior amplifiers and radio detectors and they also realized how important they could be to France's war effort. Thanks to this and other advances, France's early "electronic warfare" technology was far superior to Germany's.

Within a year of getting these Western Electric tubes, French companies began to manufacture what they called "TM valves" for the French military. Soon thereafter, the French government gave the British government some of these tubes and the British then began to manufacture large numbers of what they called "Type R valves." In 1917, the British gave the American Signal Corps (including Captain Armstrong) some of these "Type R valves" and that's how the first really useful triode tubes made their full circle back to America even though Western Electric had already produced the first true triode tubes years earlier here in America.

Edwin Armstrong's brilliant invention

After working out the mathematical theory of electron flow in the Audion tube, the brilliant Mr. Armstrong went on to invent nearly all the oscillator, heterodyne mixer and amplifier circuits we know today including the regenerative receiver I built. In fact, the regenerative receiver was one of his first inventions and he came up with it in 1911 while he was an electrical engineering student at Columbia University. It is hard to overstate the importance of Armstrong's regenerative radio because it was so clearly superior to anything that preceded it and it started a quest for producing clean radio waves using tubes and for better and better devices for amplifying tiny radio signals.



Armstrong's Regenerative Receiver.
In the earliest radios, the tube's regeneration was controlled by varying the filament voltage.
Later, regeneration was controlled by a variable bypass condenser called a "throttle."

You will notice that this regenerative receiver is very similar to the audion detector shown above, but has a feedback loop that greatly amplifies the signal. In most every respect, this radio operates on the same principles as De Forest's grid leak detector radio, but the feedback loop is a critical improvement that made this detector so outstanding. By the way, I've been experimenting with high performance crystal radios lately and I can tell you that even a simple regenerative radio, such as this one, is far, far superior to even the best crystal radio in terms of selectivity and sensitivity. With this superiority in mind, it is no wonder that radios with tubes edged out crystal sets once affordable, reliable and vastly improved vacuum tubes began to become available beginning in 1920 with the WD-11 and the UV-201A tubes.

A better kind of radio
A little history

For the first two decades of the 20th Century and all through the Great War (WW1), almost all radio receivers used a diode detector (a crystal or Fleming Valve). Now it is true that in 1911, Edwin Armstrong developed a better way of detecting radio waves, but his radio required a rare and expensive high-tech device (the Audion tube) and it needed two batteries in order to work. Armstrong's new radio was almost as simple as a basic crystal radio, but it could bring in weak, distant stations and it could separate stations that were right next to each other far better than even the best crystal detector radios and even better than De Forest's grid leak detector radios could.

As obviously superior as it was, Armstrong's radio wasn't much of a success at first because high performance, reliable and affordable triode tubes hadn't been developed yet. Add to that, World War One came along at just the wrong time and besides, there were no radio stations broadcasting entertainment programs for people to listen to. Because of these factors, the regenerative radio principle went unused for several years.

Speaking of good triode tubes, I think that it is ironic that they were first produced as early as 1912, but by law they were not allowed to be used in radio equipment. Nevertheless, it didn't matter because World War One put a stop to civilian radio development. In fact, ordinary Americans weren't allowed to even own radio equipment until after 1919. During the war, American triode tubes (developed by Western Electric) made their way to France, from France to England and from there back to America so that with end of the war, everything was in place for the birth of The Radio Age.

Around 1920, there were finally some radio stations on the air using powerful newly developed transmitting tubes and the number of stations on the air grew very rapidly. Just as importantly, there were finally some really good receiving tubes (like the WD-11 triode) for sale at more or less reasonable prices. It was these new triode receiving tubes that made Armstrong's regenerative radio a success. By the mid 1920s, people began to abandon their crystal radios in favor of tube radios, but not all at once. As desirable as it was to own a tube radio, they and their batteries were pretty expensive and many people just couldn't afford them, so crystal radios remained popular with the public until the mid 1920s. After that, almost nobody listened to the radio with a crystal set anymore, however, in a very limited way, crystal radios have remained popular with a few of us experimenters and kit builders to this very day.

By the early 1930s, Armstrong's regenerative principle lost the popularity it had enjoyed during the previous 10 years as regenerative radios were replaced by superheterodyne radios. Now wouldn't you just know it, the superheterodyne was invented by the same (then Captain) Edwin Armstrong during World War One while he was in France working on radio direction finders for the U.S. Army. The superheterodyne is a marvelous invention and, to this very day, nearly all radios are based on the superheterodyne principle. As with the regenerative radio, the superheterodyne wasn't popular at first because it too had to wait until improved tubes were available to make it practical. Just as the WD-11 triode tube made the regenerative radio practical, wonderful new tubes such as the 35 and later the 6A8 made the superheterodyne practical. So, like the crystal radio before it, technological change caused the regenerative radio to loose its popularity with the general public. However, because of its amazing simplicity and excellent performance, the regenerative radio has remained popular with a few experimenters and kit builders to this very day.

I should mention that Armstrong's regeneration principle became obsolete after 1930, but only here in America. In the 1930s, wages in Germany were extremely low and people didn't have a lot of money to spend on a radio. However, the Minister of Nazi Propaganda, the evil Joseph Goebbels, was keenly aware of the value of AM radio as a propaganda tool (as the political and religious Right Wing is today here in America) and so, under the direction of the Nazi government, a line of simple, affordable, but good performing radios (called Volksempfangers) were manufactured. Unlike the American radios of the period, the Volksempfangers had no shortwave and indeed, it was strictly forbidden to use them to listen to foreign broadcasts. As simple and inexpensive as they were, they still cost the equivalent of over $1,500 in today's money. Produced from 1933 to 1945, they were probably the last mass produced radios who's design was based on Armstrong's regenerative principle.

How I built my Armstrong regenerative radio

I am no Edwin Armstrong and when I was a kid, I knew almost nothing about radio circuits, so I must admit that I didn't come up with my radio on my own. I got the plans for my Armstrong regenerative radio from a wonderful book of science projects called "The Boy Electrician" by Alfred Morgan. The first edition of this book came out as early as 1913 and was updated every few years with my copy printed in 1940. Much of the technology in the book was over 50 years old even then, but it was full of good, basic science and many of the projects were something a kid could build and learn while doing. One of the projects was an elaborate, but old fashioned crystal set that looked difficult to build, but the project that really appealed to me was a one tube Armstrong regenerative radio.

In the early 1920s, the first hand blown tubes and factory-made regenerative radios (such as the Arieola Senior) were still very expensive, however these little radios began to become very popular and many young people built them from kits and from a series of wonderful plans published by the U.S. Government. Making one of these radios at home could save a person a lot of money because, as I mentioned, factory radios were so expensive. However, by the time I built my little radio things had completely turned around. The fact was, I could have easily bought a used five tube factory built AM radio for less money than what I spent on parts for this little radio and I wouldn't have had to spend any time building it. Nevertheless, this one tube radio was something I could build myself and something I could learn from so the education I got and the satisfaction I received was priceless. God knows that I wasn't learning much in school, so I needed to learn something.

For parts, I bought some of them new, but the headphones I reused from the original crystal radio my aunt Helen gave me. The 1H4GT triode tube, the carbon resistor, the sockets, the potentiometer and the silver-mica capacitors I bought at the Sears Warehouse that we used to have here in town and where they repaired Sears "Silvertone" radios and record players. I remember the clerk wondering what in the world a dumb kid like me wanted with one of those 1H4 tubes, which were pretty old fashioned by then and they only had one of them in stock. I also remember how amused the guys behind the counter were when I asked for "two, two hundred and fifty micro micro farad CONDENSERS." Even by then, the word 'condenser' had gone out of style.

The tuning coil was another matter. The book called out "standard" plug-in coils, but nobody had them or had even heard of them -- they must have been for some very, very old radios. There were plans for winding your own coils, but I couldn't get or make the coil forms so I had to wind my coils on an old toilet paper tube (which is now falling apart and I had to 'dope' back together). By the way, I wanted to use this radio to listen to shortwave in addition to the broadcast band. Just as I had made my own broadcast band coil, I intended to make up additional coils for the shortwave bands, but I never made those coils because I couldn't find any more plugs for sale in town. Nevertheless, there is no reason why this radio would not work up on shortwave, so maybe I'll try

to find plugs that will mate with my socket and wind some more coils for my old radio as I had originally planned to do so long ago. One of these days -- maybe.

I didn't have the tools or the experience or the skills to build this project the way it was pictured in The Boy Electrician, but I came up with a way of building it using what skills and materials I had. I picked out a nice piece of pine panel, left over from a nearby house under construction, to be the main chassis. On that board I mounted the tube and other components as shown below. To make a box for the batteries under the chassis board, I sawed and nailed up some left over pieces of redwood fence boards. It was really crude and really ugly as you can see, but I was just a kid without any tools or any expert help. Here is what it looks like today:

Main tuning control in the center, regeneration control on the right.
The large gear drive vernier tuning dial was added recently replacing the large knob I originally used.
The small knob to the right is the regeneration (throttle) control. Originally that knob operated a potentiometer as the throttle, but now it controls a variable condenser.
Isn't that big glass tube absolutely beautiful?

On/off switch, antenna, ground and phone connections.
You can look right down inside the Electropolis and see all the gilttering elements that makes up the thermionic tube that is the heart of this radio.

Rear showing the "battery box,"
Not exactly an Atwater Kent, but pretty good for a 13 year old kid.
You know, I'll bet I was the only kid in town who made one of these radios
and I am still proud that I made it without any adult encouragement or help.

Today I live in a small city, but way back in 1958 Santa Maria was just a large town. Nevertheless, just about everything could be had locally and in many respects, hardware and even electronic parts were easier to get back then. Today all the local merchants have been put out of business by huge mega corporations owned by faceless boards located god-knows-where and today my town's stores only carry those Chinese made products that are quick selling and pre-manufactured. Indeed, all the "hobby shops" in town closed their doors years ago and it is nearly impossible to get those kinds of items anywhere in the region. Of course, there is the Internet, but it was so much easier and so much fun to simply walk into a well stocked hobby shop, look around and let your young creative juices flow.

Before I leave this topic, I think I need to say something about how I powered this little radio. All vacuum tubes require a hot cathode to "boil off" electrons and most tubes have a cathode that is indirectly heated. An indirectly heated cathode can operate on AC which means that the radio doesn't have to have a battery to heat the cathodes, however indirectly heated cathodes require a lot of heater power and are not suitable for battery operation. The 1H4 tube was designed for low power operation so its cathode is the filament and because of that it operates at low current (only 15 milliamps). Because the 1H4's filament requires so little power, I could operate the filament for many hours using one of those huge "telephone" cells (called an 'A' battery) that were so common back then. Today I use a single 'D' cell and it lasts at least as long as the old telephone battery used to.

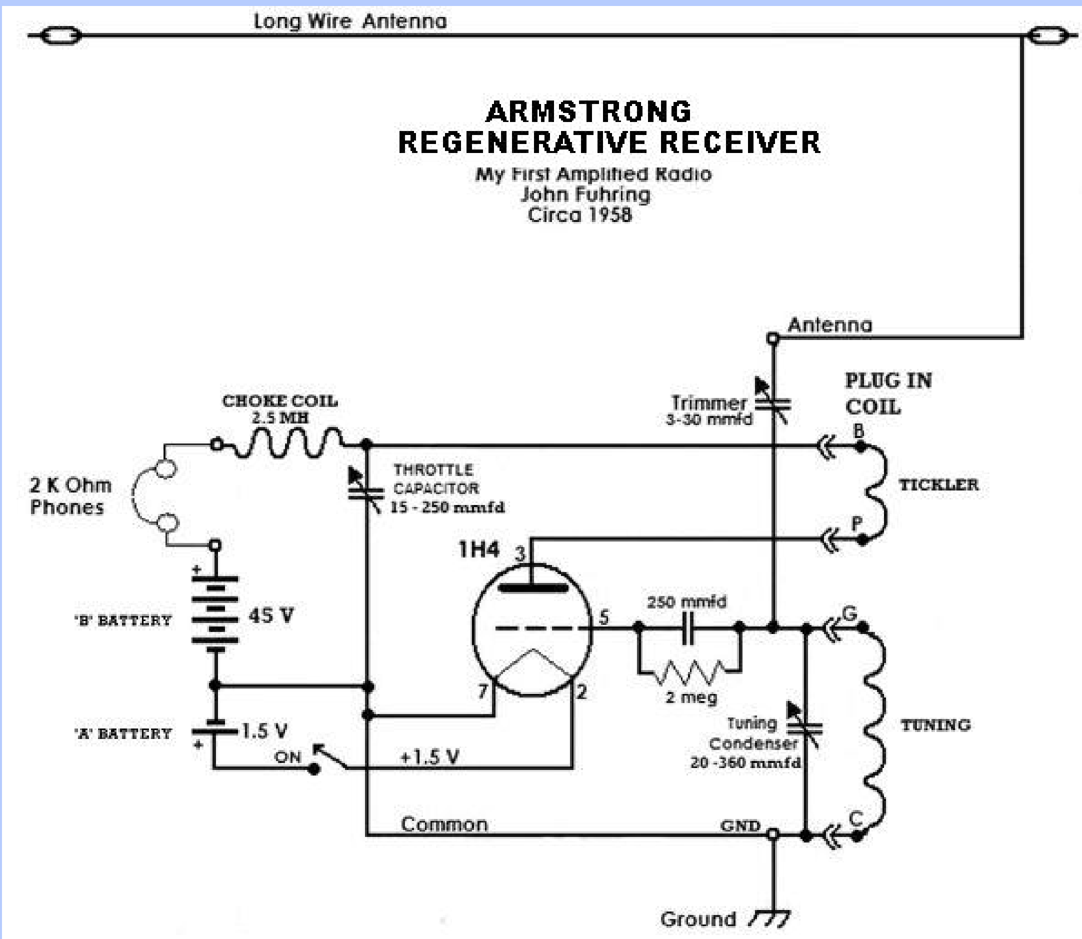
In 1958, to power the plate circuit of the 1H4 tube, I used a small (and what was then a commonly available) 45 volt portable radio battery (called a 'B' battery). These batteries haven't been made in 50 years, so to make

my old radio work again, I made up a 'B' battery by ganging together five 9 volt batteries until I had 45 volts.

A technical discussion of how an Armstrong Regenerative detector works

(Note: this discussion assumes you know something about resistance, capacitance, inductance and tuned circuits. If you slept through science class, you may wish to skip this section.)

To pick up radio signals, a piece of wire has to be strung up as high and as long as practical and some kind of a ground must be connected too. Passing radio waves from a distant transmitting station electro-magnetically couple to this wire and, in response, a very tiny, but high frequency electrical voltage appears on the wire. The frequency is so high that the signal passes through the Trimmer capacitor and starts a alternating current flowing back and forth in the coil between points G (and the top of the tuning condenser) and point C (and the bottom of the tuning condenser). That tiny high frequency alternating current is then coupled through the "grid tickler" network consisting of a 2 meg resistor and the 250 mmfd capacitor (to the right of the coil/condenser) and from the "grid tickler" the signal appears on the grid, pin 5 of the 1H4 tube.



My Regenerative Radio's "improved" throttle control

Notice that instead of using a coupling coil, the antenna signal is connected to the tuned circuit through a trimmer capacitor. In a crystal or similar radio, this actually works better for weak signals, but it results in such broad tuning that broadcast stations interfere with each other very badly and a radio like this is useless. A more technical way of saying this is, the resulting radio would have unacceptably poor **selectivity**. Using Armstrong's design, the tuning is very sharp because the sharpness or Q of the tuning circuit is multiplied every time the signal goes through regeneration. Injecting an antenna signal this way brings in weak signals, but, thanks to regeneration, the selectivity is very sharp and is better than the best loosely coupled crystal radio. In fact, the selectivity of a regenerative radio like this approaches the selectivity of a good superheterodyne radio.

The radio signal is greatly amplified in the tube by the grid acting like a valve that varies the stream of electrons that flow from the hot filament (pins 2 & &7) to the anode (or plate) of the tube (pin 3). High frequency

radio currents then flow through the "tickler coil" across pins B and P and through the **regeneration control** capacitor (the **throttle**) to ground -- this is called "bypassing to ground." When radio frequency currents flow in the tickler coil, they produce a radio frequency magnetic field that is coupled back into the main tuning coil (G &C) through the principle of "mutual inductance" (discovered in the early 1830s). The strength of that current flow and resulting magnetic field is adjusted by the regeneration control capacitor (the throttle). The larger the capacitance, the more current and the stronger the magnetic field will be and the stronger the magnetic field, the greater the signal (called a "regenerated signal") that is fed back into the main tuning coil.

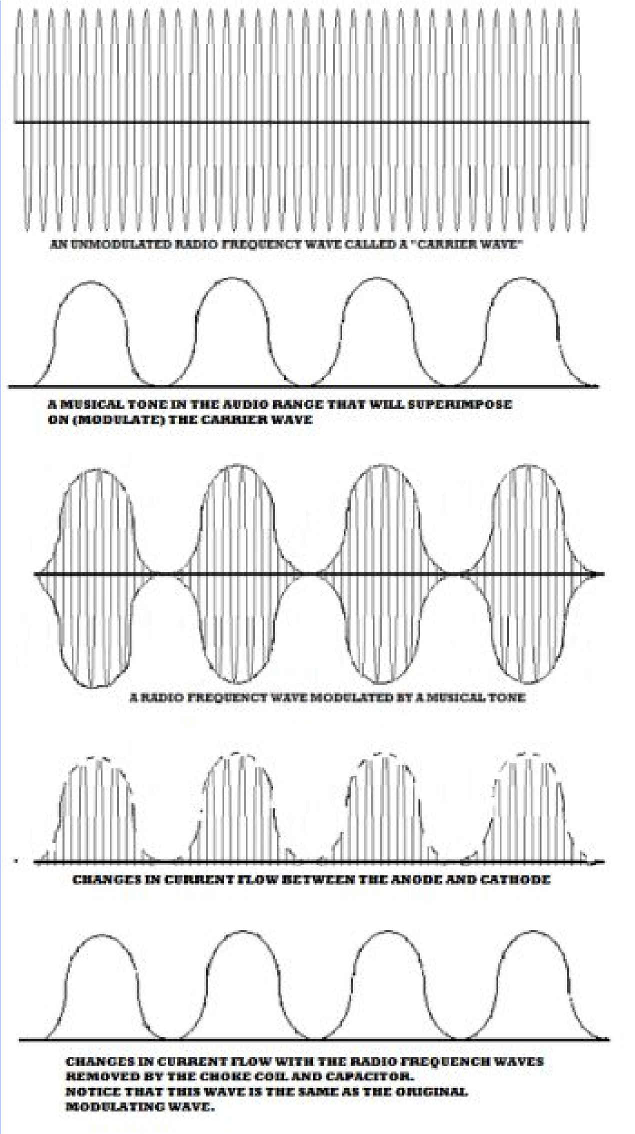
The "regenerated" signal that is magnetically coupled to the main tuning coil is coupled to the grid of the 1H4 through the grid tickler network (250 mmfd capacitor & 2 megohm resistor) and the signal is amplified again. This goes on and on and, depending on how the regeneration control is set, the overall amplification may be several hundreds or even thousands of times the original signal level. Amplifying a signal over and over again like this would be just great, but this kind of amplification (called "positive feedback") can easily be overdone and you don't want to over do it.

It is of utmost importance that the amount of "positive feedback" (regeneration) be set very carefully. If the **throttle** is set up too hot with too much bypassing to ground, the tube will go into self-oscillation and a squeal will be heard as the original radio signal "heterodynes" with the oscillation of the tube. On the other hand, if the throttle is not set up hot enough, the tube doesn't amplify very well. Finding that elusive "sweet spot" of just exactly the right amount of regeneration is why a smooth throttle control is necessary.

If you will look at the upper left of my radio's schematic above, you will see something labeled '2.5 mH CHOKE COIL.' A choke coil blocks high frequency radio current, but allows audio frequency current to pass through. A choke coil must be used here or the bypassing will be very chaotic and the regeneration level (throttle) will be very unstable or it won't work at all.

During all this amplification going on inside the tube, the parts of the original radio signal (the carrier wave and the audio sidebands) are all mixed together (or heterodyned) and audio frequency currents are produced. This audio frequency current passes through the choke coil and from there, the current flows through the electromagnets in the headphones, those currents cause changes in the magnetic field that attracts the iron diaphragm of the headphones causing them to vibrate and it's those vibrations that I hear as music and voice sounds.

An alternative and the older way of looking at how the regenerative detector works is called "demodulation by grid rectification." The way this is supposed to work is as follows: the radio frequency wave, that has been amplified by regeneration, has, by the nature of it being an AC wave, positive and negative components. These components vary in strength in step with the audio wave that was superimposed on it when it was originally transmitted by the radio station (see the diagram below). When the radio frequency wave with this audio wave superimposed on it reaches its maximum positive voltage in the tank circuit, it also reaches its maximum value on the grid of the tube by being coupled through the *grid tickler network*(1 megohm resistor and 100 pF capacitor) -- supposedly by "charging" the 100 pF capacitor. Electrons from the hot cathode are attracted to the now positive grid and current flows, but an even greater current flows between the cathode and the anode. When the radio frequency wave turns negative, current flow between the grid and the cathode is cut off and this cuts off the current flow to the anode too. This creates a very rapid series of current pulses across the tube that vary at the radio frequency rate, but create an average current flow at the audio rate. When these varying current pulses are smoothed out by going through the choke coil and the bypass capacitor on the other side, an audio frequency wave results and may be heard in the headphones. In this way, the modulated radio frequency wave appears to be "rectified" as if it was going through a crystal or Fleming Valve diode, but because this current flow is greatly amplified by the enhanced current flow between the cathode and anode, the audio signal is likewise greatly amplified.

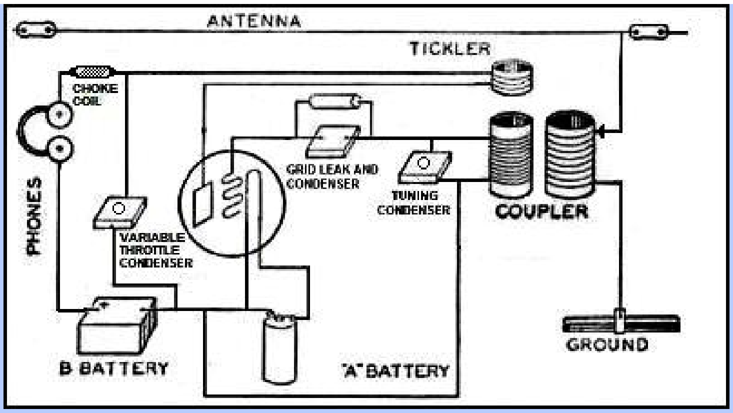


Audio and radio frequency waveforms used by or produced by a regenerative detector.

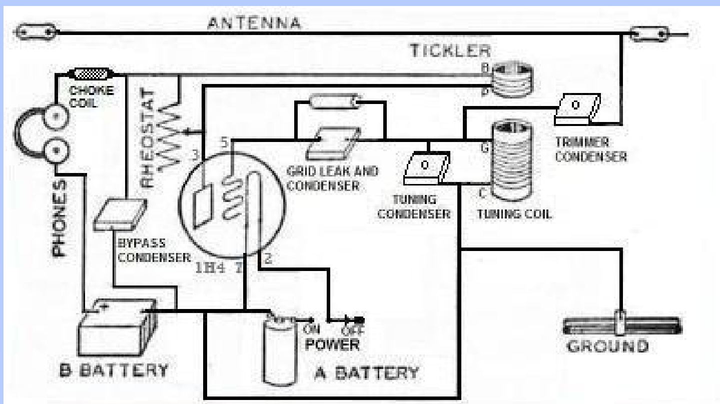
Personally, I think much of "grid rectification" theory is a bogus way of looking at what is happening in a regenerative radio. An FET can not pass the equivalent of "grid current" and yet an FET regenerative radio works and sounds exactly the same as a vacuum tube radio. It is my opinion that the grid tickler capacitor is not "charged" by the grid tickler resistor but simply acts to couple the signal from the tank circuit to the grid (or *gate*) of the amplifier tube or FET. The grid tickler resistor (because it is so large) functions simply to self-bias the grid of the tube as passing electrons from the cathode are picked up, makes the grid slightly negative and thus regulates the electron flow in the tube automatically. In the FET, there can be no self biasing, so that at the "*source*" (cathode) of the FET, a biasing network consisting of a resistor (usually around 2.7 Kohm) and a capacitor (usually around 10 MFD) is used to make the *source* slightly positive with respect to ground. The *gate* tickler resistor is there to simply bypass the *gate* to ground potential (giving the equivalent of a small negative voltage with respect to the *source*). Of course this is only an opinion because I am no expert and this is simply my personal (and perhaps flawed) understanding of what is going on in these circuits.

The importance of smooth control of the regeneration

To control the amount of regeneration, you need a way to carefully increase or cut down on how much radio frequency current is flowing in the tickler coil. Too much current and all you get is a squeal, but too little current and you don't hear anything. This is called "varying the amount of bypassing" and you have to have it set exactly right for best performance. In the real old days of radio, this regeneration control was called "the throttle circuit" because they "throttled" the regeneration up and down just like you controlled the speed of an car's engine by its "throttle" control. For throttling in the old days, they always used a variable capacitor.

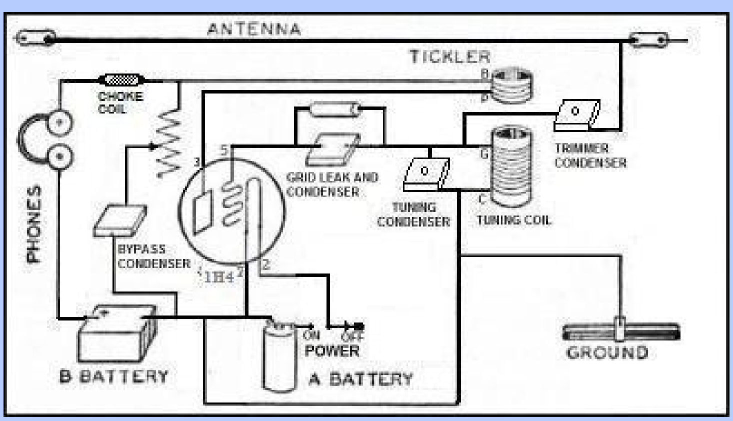


Typical Regenerative Radio of the 1920s.
A variable "throttle " condenser was a common and excellent way to control the amount of bypassing and thus control the amount of regeneration.



Original Regenerative Radio Design from The Boy Electrician.
The amount of regeneration was "throttled" by a rheostat across the tickler coil.
This proved to be very difficult to control and so I came up with a better way on my own.

Well, at the time I built my radio, variable capacitors were expensive, hard to get and hard to mount, so a variable capacitor to control regeneration was out of the question. As suggested by the book, I used a rheostat to "swamp" the tickler coil and control the regeneration that way, but soon discovered that this method worked very poorly and the right amount of regeneration was just about impossible to control. I then came up with what I thought was a very clever idea.



My radio with its modification as it would have appeared in The Boy Electrician.

What I did was vary the effectiveness (amount of bypassing) of the 250 mmfd capacitor by putting my rheostat in series with the capacitor. Electrically, this was more or less the same thing as using a variable capacitor --- sort of As it turned out, this was still a poor way of controlling the regeneration. Still, it was a vast,

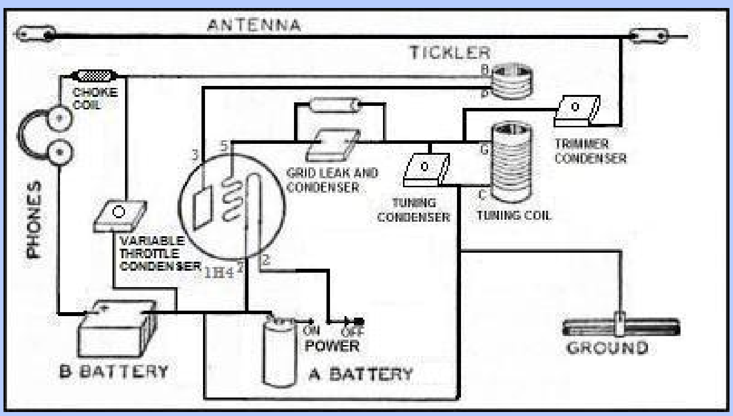
vast improvement over the Boy Electrician's original design and I really felt that Armstrong would have been proud of me.

May 26, 2011. I make an important discovery after only 50 years.

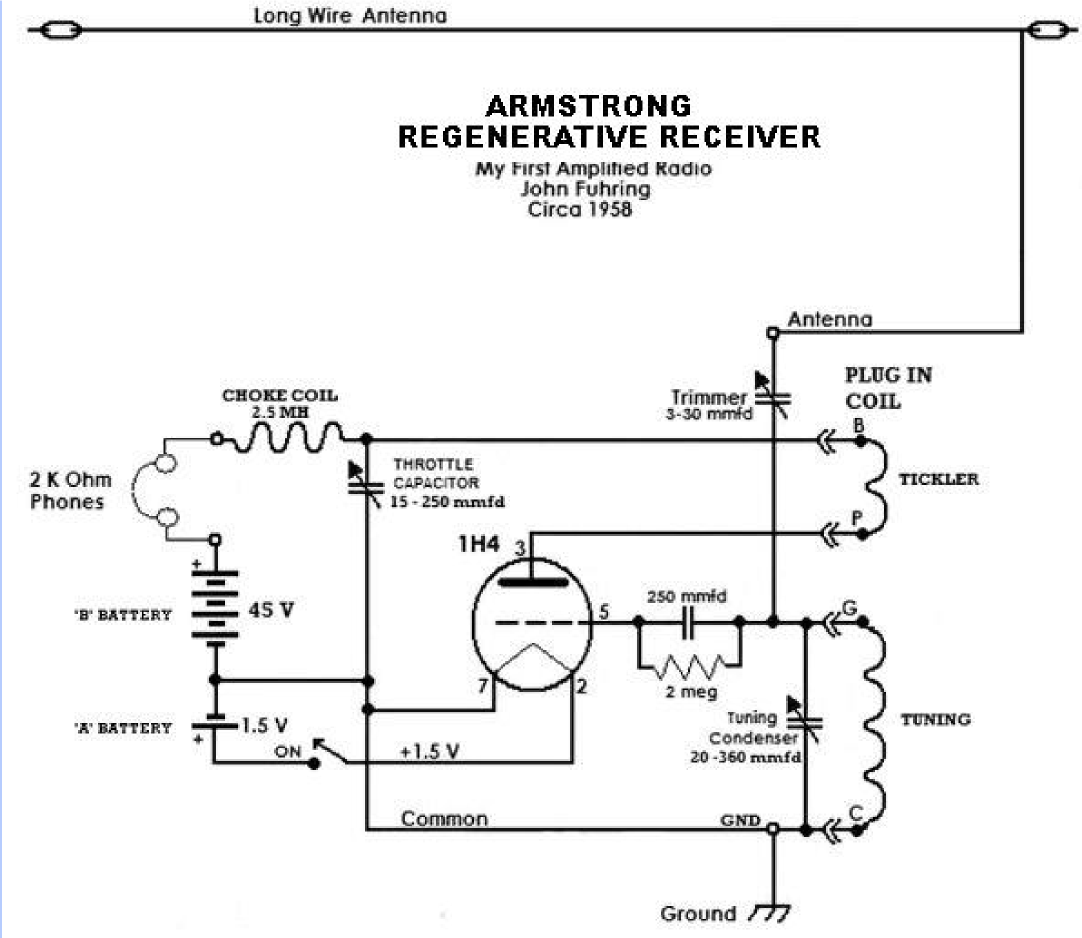
I have a confession to make. Yesterday I modified my first radio and now it isn't exactly the same as when I built it so many years ago. I had to because facts came up against my pride and the facts won.

For the last several evenings, I have been "DX'ing, " on the broadcast band to see just how well my old radio performs. I originally discovered the defects in the design of the Boy Electrician's regeneration control by spending time with it and becoming dissatisfied with its performance. By recently spending time searching out weak and distant signals, I once again became dissatisfied with my radio's performance. While my throttle control method is a vast improvement over the Boy Electrician's method, it has its own defects that I finally decided needed addressing. While trying to tune in weak stations, I noticed that the tuning would shift and weak signals would disappear as I adjusted the throttle and this became more and more dissatisfying.

A few days ago I experimented with a variable capacitor arranged as a throttle. Of course, this is the very same way people in the 1920s used to do it. I soon discovered that the old timers were right after all and that a variable capacitor is clearly the superior way to control the throttle. Somewhat reluctantly I removed the potentiometer/capacitor throttle arrangement I was so proud of and put in a variable capacitor. I completed the installation yesterday and last night I was very gratified by how much better the old radio performed. The DX conditions these last few nights have been extremely poor, but I was able to bring in a Los Angles station, KGO in San Francisco and a Reno station clearly, if not loudly. The new old-fashioned throttle circuit made all the difference and it was a joy to use.



Using a variable "condenser" for a feedback throttle is still the best way to go.
This diagram is the circuit configuration I think the Boy Electrician book should have presented.



My Regenerative Radio today using modern electronic symbols.
Doing a little research on how these radios were originally built in the 1920s, I discovered that nobody used a potentiometer to swamp out the tickler coil and the original way using a throttle capacitor was the best way to control the regeneration.

Something that is part of the Scientific Method

Well, I think there's a good lesson here and even at my age, it is good to experience such things. I have crowed loudly about my superior way of throttling the tickler coil, but now I'm forced by experimental results to admit that my method is not the best. The lesson here is just this: if proof is offered that there is a better way to do something, you must abandon your old ideas no matter how clever you originally thought they were. Anything else is a dishonest attempt to deceive yourself or others for the sake of foolish pride. Just because something has been around for a long time, that doesn't mean it is worth hanging on to if scientific evidence says that there is something better.

Some final words on my early radios

Well, that's the story of how I got interested in radio and the story of the first radio I ever made using an amplifier. I am especially fond of this ugly little radio because it's my earliest project that has survived to this day. I didn't invent the radio and yes, I got the plans out of a book, but still, it did contain some of my own ideas. Beyond all that, building the radio and getting it to work taught me several important things regarding how signals flow through circuits, how those circuits work and how vacuum tubes amplify. It was this early specialization that lead to my career in electronics and, although now retired, I still find enjoyment is this sort of thing.

By the way, I have restored one of those really excellent Heathkit CR1 crystal radios. I have also designed a tiny crystal radio kit based on the Heathkit and have been having fun experimenting with crystal radios once again. The truth is, my Armstrong radio is far, far superior to either one of those crystal radios in terms of both selectivity and sensitivity. My recent experimenting has reminded me once again why the crystal detector, after it got the Radio Age started, was abandoned for Armstrong's designs.

During that period after 1918 and until they were superseded by TRF and the early superheterodyne radios in the 1920s, radio enthusiasts knew that even a simple regenerative radio (like mine) is clearly superior to even the most elaborate crystal radio. The thing that held these early radios back was the really awful and terribly expensive early triode tubes that were the only things then available. Nevertheless, those early regenerative radios were so clearly superior to even the best crystal radios, that a lively market for those early triode tubes developed. Now that people could see how good tubes made better and better radios possible, a demand for better and better tubes developed too. This market drove the infant electronics industry so that by the mid 1920s, engineers and scientists had developed high-tech tubes sufficiently advanced to allow the development of almost all the modern circuits that are used today (using solid-state amplifiers, of course).

Early 20th Century design, but using a crystalline triode

Today a regenerative radio based on Armstrong's design can be made with a tiny and inexpensive transistor in place of the triode tube. If you use a Field Effect Transistor (an FET), the circuit layout is almost identical to the electron tube layout of the early radios. The FET circuit shown below works on exactly the same principle as the vacuum tube models except that there is no need for an ' A ' battery and the 45 volt ' B ' battery is lowered to just 9 volts. Instead of connecting the "grid tickler" to the grid (pin 5), it would be connected to the 'gate' of the FET and the 'drain' would be connected as the anode (or plate - pin 3) and the 'source' would connect to the ground (or anode - pin 7).

Other advantages of using a transistor as the regenerative detector are:

1) An FET is so much cheaper and easier to obtain than something like a 1H4 tube,
2) your one battery will last so much longer than the triode's 'A' battery,
3) the radio can be made smaller,
4) the radio is much more rugged and may even be dropped on the ground without ruining it,
5) there is no filament to ever burn out.

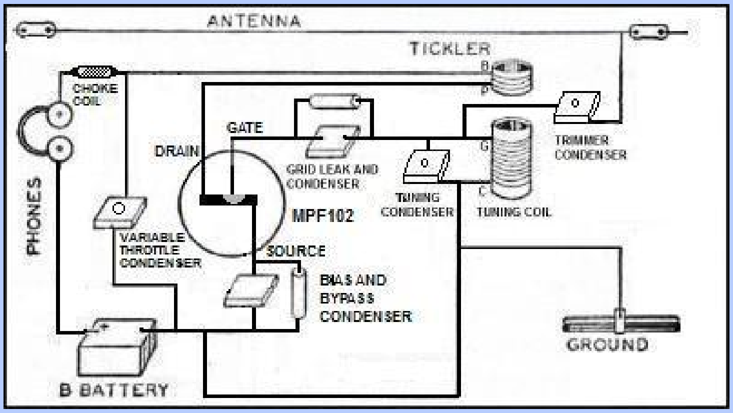
If you are interested in building simple crystal radio or an Armstrong regenerative radio such as my Boy Electrician radio, I urge you to consider building the "Geezerola" radio shown below. It is so sensitive, you won't need an antenna more than a few feet long and it is so selective that you will be able to hear individual stations without them talking over each other -- even the ones that are close by on the dial. The radio is as simple, cheap and easy to build as the most basic crystal radios, but it out performs even the best and most elaborate crystal radios.

The 2012 Old Geezer Electrician Radio

An Armstrong Regenerative radio using a
Field Effect Transistor instead of the 1H4 tube.
This radio was built using the same construction
techniques I used to build my 1958 radio

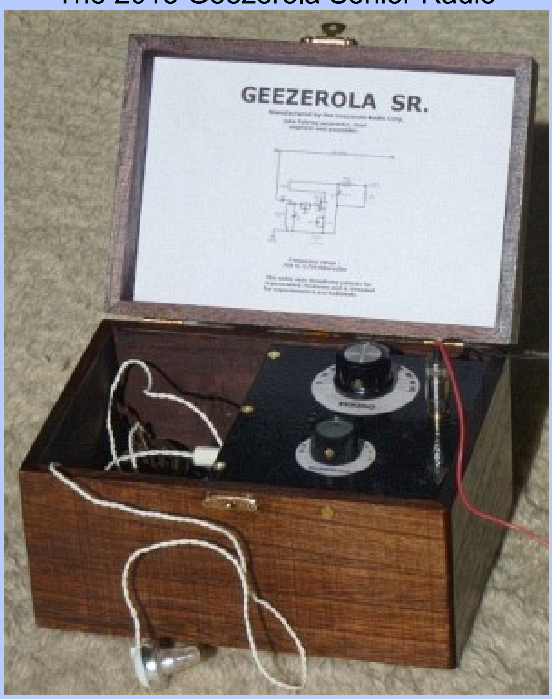
I built this regenerative radio 54 years after I built the "Boy Electrician" radio. I used the same simple construction techniques and the simple and ordinary tools I

used to build my earlier radio. There is a link to my "Geezerola Radio" story at the end of this story.



This is the schematic of my FET radio as it would have appeared in The Boy Electrician. Of course, there were no FETs in those days. Notice that it is virtually identical to the original tube design.

The 2013 Geezerola Senior Radio



My "Geezerola Senior" is the same as the radio shown above, but a lot better looking.

A final question you must ask yourself

A question remains though. Why would anybody today want to go to the expense and labor to build their own AM radio receiver? Yes, it would be as good a learning experience as it was when I was a kid, but today, in many areas of our country, the reward of listening to something that would bring you joy is missing. In many, perhaps most places here in the U.S. there is today nothing a kid would want to listen to on AM radio or, in my opinion, nothing that would be good for a young mind to hear.

A Personal Lament On The Fate of AM Radio
(You don't have to agree with)
(Please skip to the end if you don't like biased opinions.)

I consider myself very lucky to have been doing all that I did at a time just before AM radio took its fatal plunge and started to degenerate into the "Hate Talk Radio" that we have today. Back when I was having so much fun doing all this experimenting, AM radio still had on it things that were well worth listening to and not poisonous to young minds as it too often is today. Elvis, James Dean, Fats Domino and other popular music stars were still on the AM dial as were all kinds of non-political news and entertainment. I remember there was a

single very hateful and hate-filled "religious" radio station in town, but I avoided that part of the dial. Today and for a long time now, there is in my broadcast area absolutely nothing on AM radio that I want to listen to or I would want a young person, who has not developed his critical thinking yet, to hear.

Several years ago I wanted to make up a basic radio kit for my young nephew and see if he would find the same magic and fascination in electronics that I found when my aunt gave me a similar radio kit. I had been extremely impressed with my nephew when he was in elementary school and thought he'd be the perfect candidate for this sort of thing. I started to gather up the components for one of these radios and started listening to AM radio once again to see what was on. I listened to all the strong stations that a crystal radio could hear and I was sincerely shocked and disappointed at what I heard blasting all day long, every day. All that is left of my local AM radio (and AM radio in most places in the U.S.) now is this retched so-called "Christian" Fundamentalism and so-called "Conservative" hate talk partisan propaganda. Certainly nothing that is good or inspiring to help a young mind develop and certainly nothing a young person should listen to before he or she has achieved enough maturity whereby the difference between indoctrination and learning can be discerned.

Yes, I was shocked at what I was hearing all over my local AM band so I scotched the idea of trying to get my nephew interested in radio the way I had. It probably wouldn't have worked anyway because, as my nephew transitioned out of elementary school, he soon dropped all interest in everything but motorcycle and truck racing. Still, I feel badly that AM radio has degenerated into what it is today and that I was never able at least try to introduce my nephew to that thing that I found so rewarding all my life. It is also sad for me to observe that, with the advance of digital technology and the Internet, it is probably just a matter of time before the Broadcast Band and Short Wave radio is altogether extinct and these wonderful old tube radios will become as quaint and useless as telegraph sounders.

The warning I'm trying to give is just this: before you build or have a young person build any kind of AM radio, check your local broadcasting to see if there is anything good to listen to. If it is all political or religious haranguing, think about building something else.

P.S. My nephew finally "found" himself and is now an apprentice electrician and absolutely loving it and all without the "help" of uncle John.

THE END

Having arrived this far, obviously you have a superior attention span and reading ability that far exceeds that of the majority of web users. I highly value the opinion of people such as yourself, so I ask you to briefly tell me:

Did you enjoy this article or were you disappointed?

Please visit my guest book and tell me before you leave my website.

If you have any detailed comments, questions, complaints or suggestions, I would be grateful if you would please **E-mail me directly**

After 55 years, I have just built a radio based on the same design as this radio that you might be interested in

An Armstrong "Crystal" Radio

from "The Old Geezer Electrician"

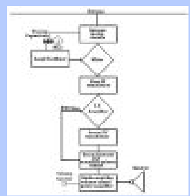
Here's a easy to build radio of the exact design and performance, but nicer looking

[The Geezerola Senior Regenerative Radio]

You might like to read the story of my Armstrong regenerative radio that tunes shortwave and uses an FET for the detector,

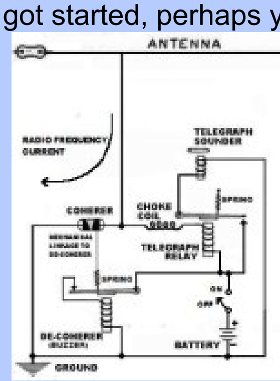
[My Regenerative Shortwave Radio.]

If you'd like to learn more about Armstrong's contributions to radio design, please take a look at my essay:



[Basic Elements of Armstrong's Superheterodyne Radio]

If you are interested in how radio got started, perhaps you would like to read my essay on



[The Coherer and other early radio detectors]

If you are interested in learning more about the kind of radios that preceded the regenerative and later radios, I have a story about

[A high performance Heathkit crystal radio]

I've completed a prototype crystal radio kit similar in design to the Heathkit CR1 that perhaps you would like to look at.

[A simple but high performance crystal radio for advanced students and hobbyists.]

If you like reading about more complex homemade radios, perhaps you would like

My Magnum Opus ham radio story

or you can

Select some other really entertaining radio article

or, as a last resort, you can

Return to my Home Page and look for something else

Notes

* I have recently come to the conclusion that De Forest's Audions behaved more like thyratrons than triodes. I believe that the reason they work so well as radio detectors is indeed because they have some gas in them. It wasn't until many years later that scientists, who knew much more about quantum physics, were able to explain that it was a "avalanche effect" where a few electrons flowing from the hot cathode and under the influence of the electric field of the grid could cause the electrons of the gas molecules to be released in great quantities and thus a small current in the tube would turn into a large current very rapidly, thus amplifying the original small signal. It is a fact that some tubes used by the British Navy had a special chamber where additional gas could be added to the Audion if it started to detect radio waves poorly.

With this in mind, perhaps it isn't so surprising that De Forest didn't understand his own tubes, but that doesn't explain the fact that he never seemed to understand how electrons moved in a high vacuum tube and how his and Armstrong's regenerative detectors worked. To me, De Forest is a real enigma. He made some solid contributions to the development of early radio technology, but for him to claim that he was the "Father of Radio" and then for him to later publish his silly rants regarding the "misuse" of his "child" (like broadcasting terrible stuff like Pop Music and advertisements) is just plane crazy and, for me, it shows what a fool the guy was.
Please use your back button to return to the story.

AWSH.ORG

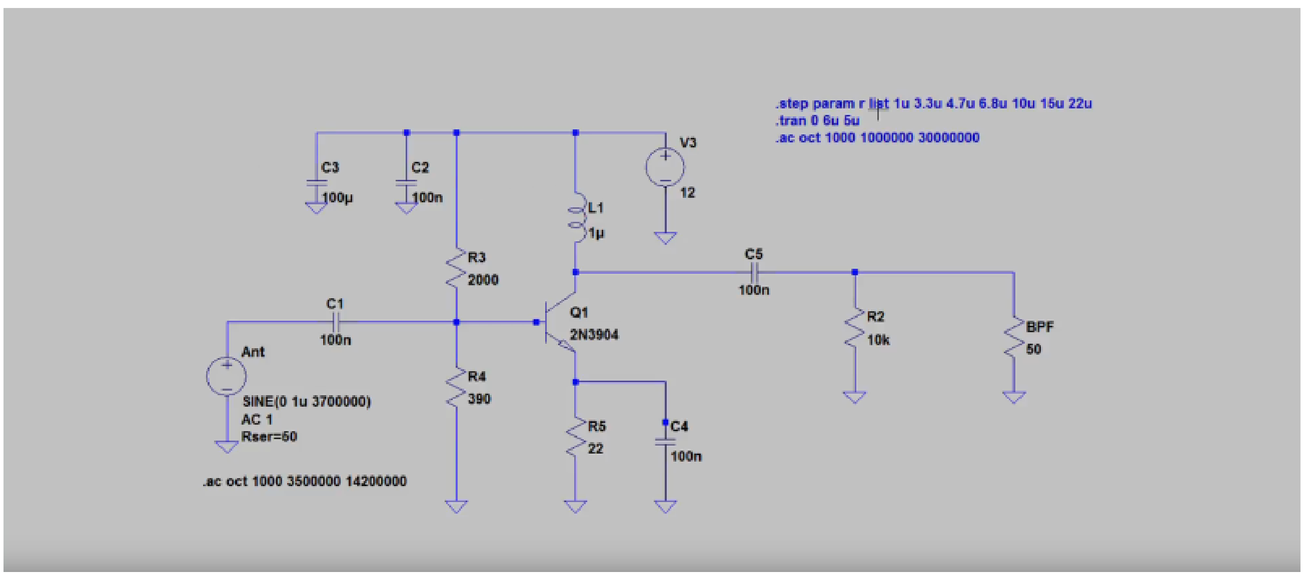
stuff that i do and things that i make

rf amp

PUBLISHED SEPTEMBER 6, 2017

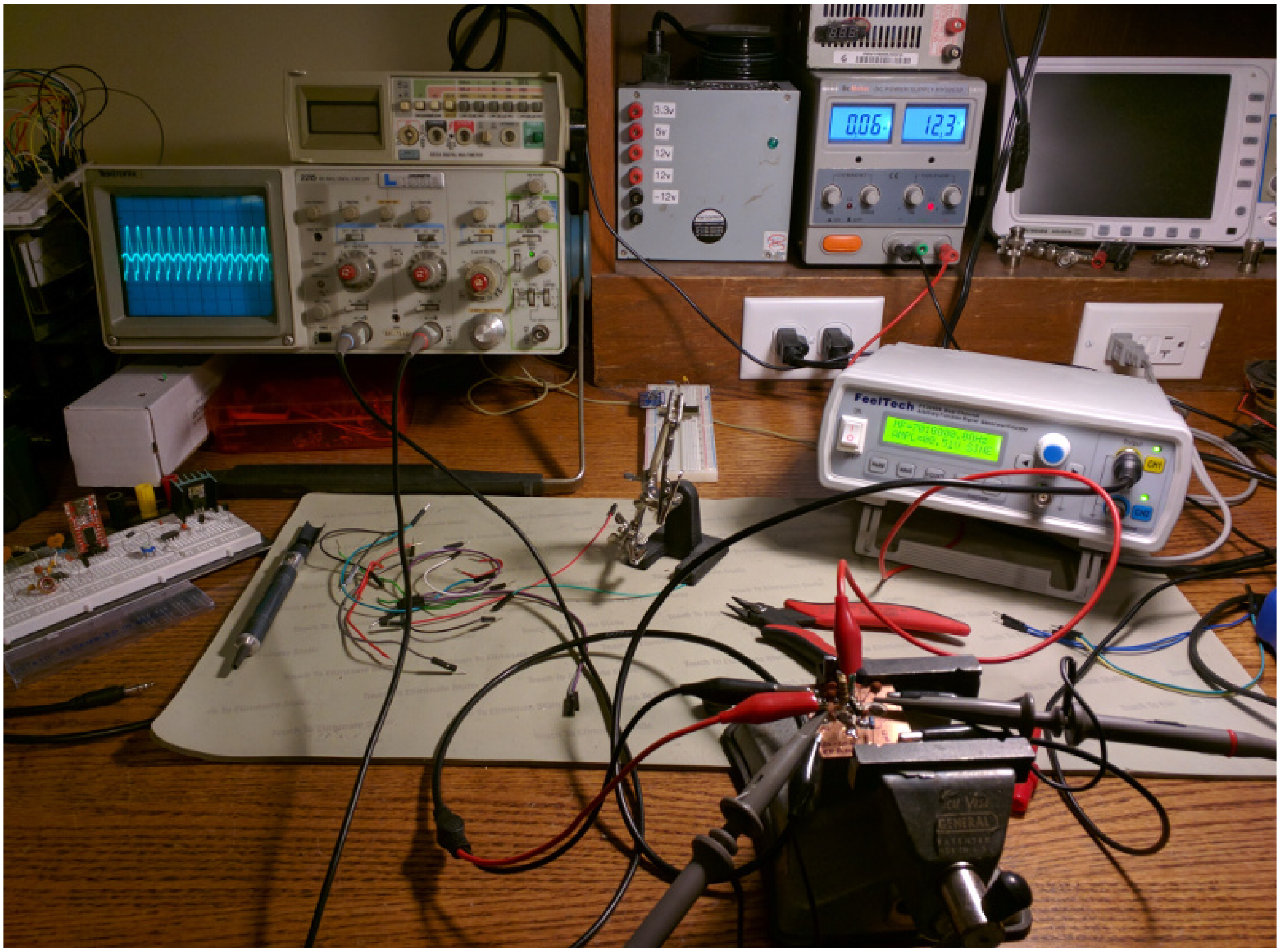
I ran across a youtube channel by a guy named Charlie Morris, and it has inspired me to attempt to homebrew a new SSB transceiver. He is currently doing a series of videos of a homebrew superhet transciever from scratch. I finally had a bit of free time last night to work on something, so I put together Charlie's RF amp.

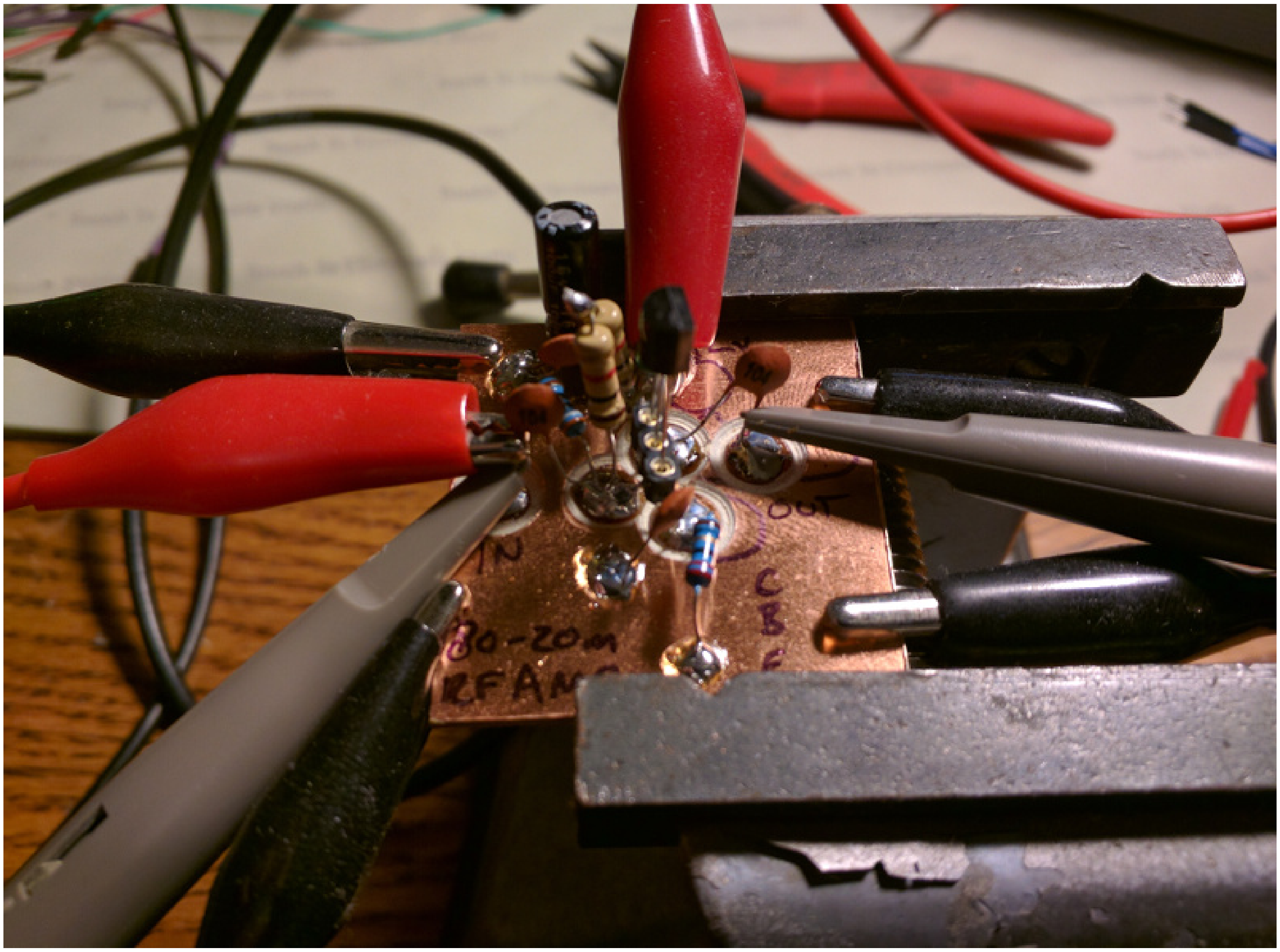
Here is the schematic.

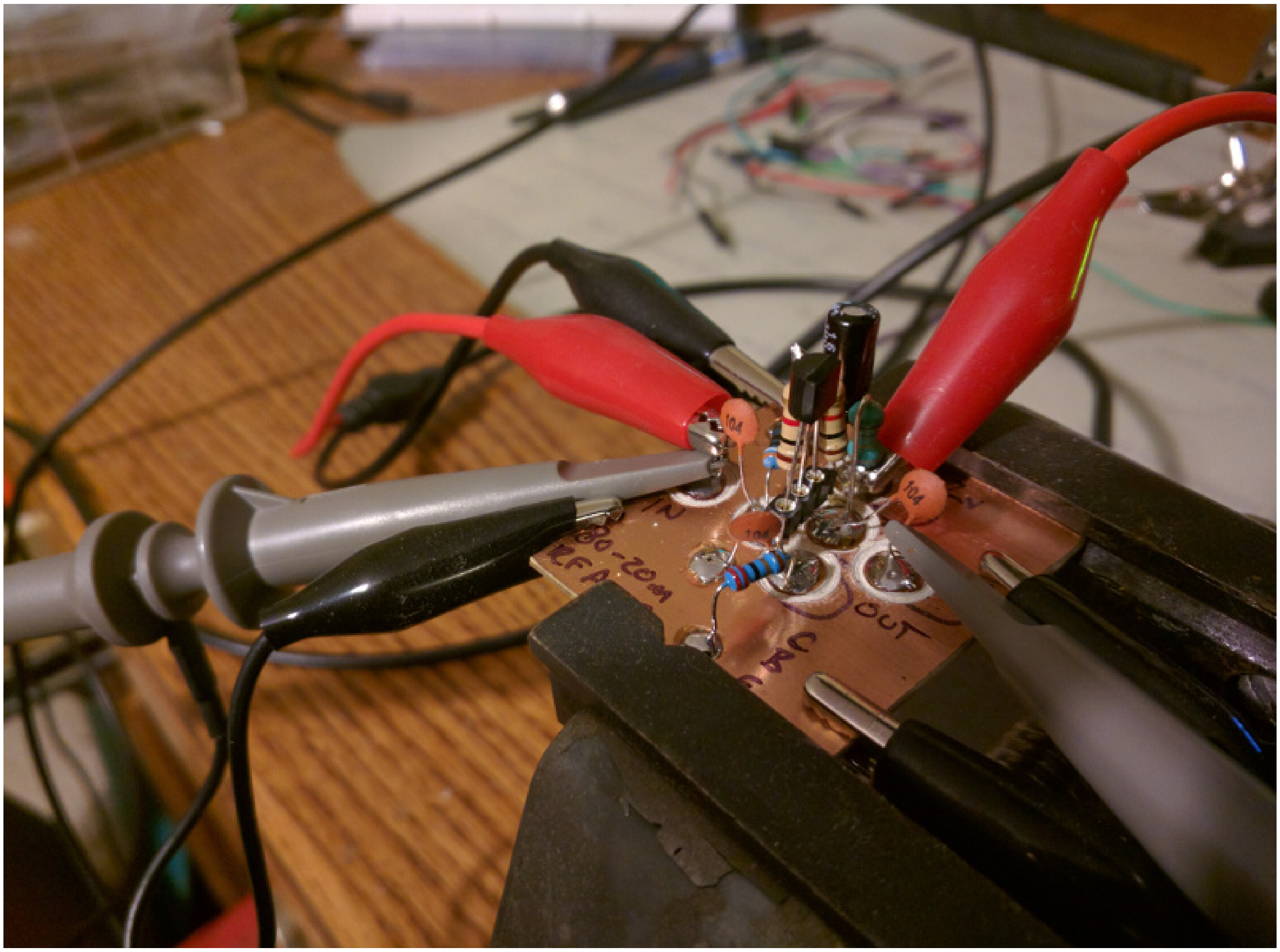


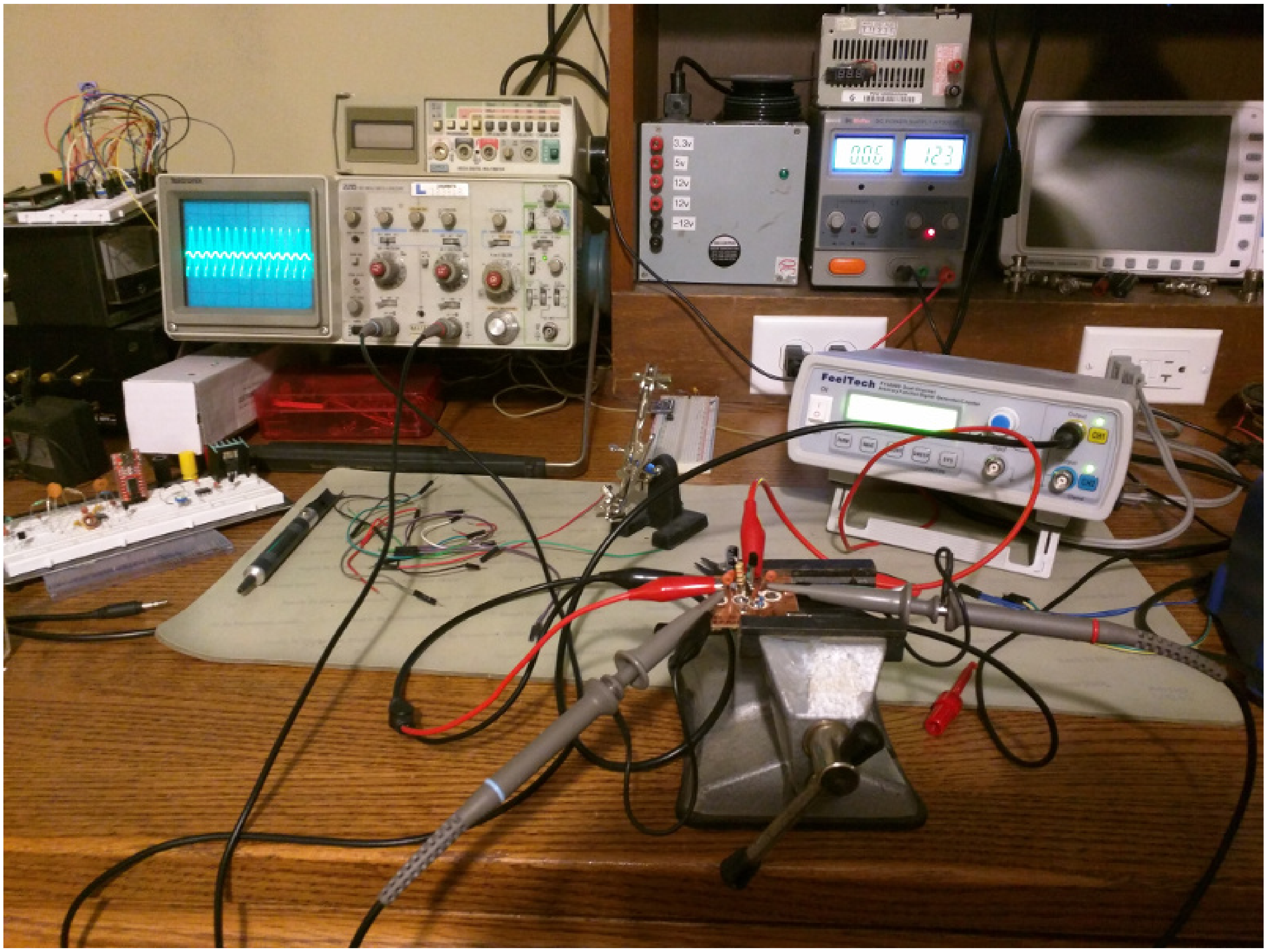
It his video, he goes over the calculations for finding the values of the various components in the amplifier, but I just went with what he used.

I put the circuit together on a small piece of copper clad, but I used sockets for the transistor, so I could swap them out and experiment with a few different types.

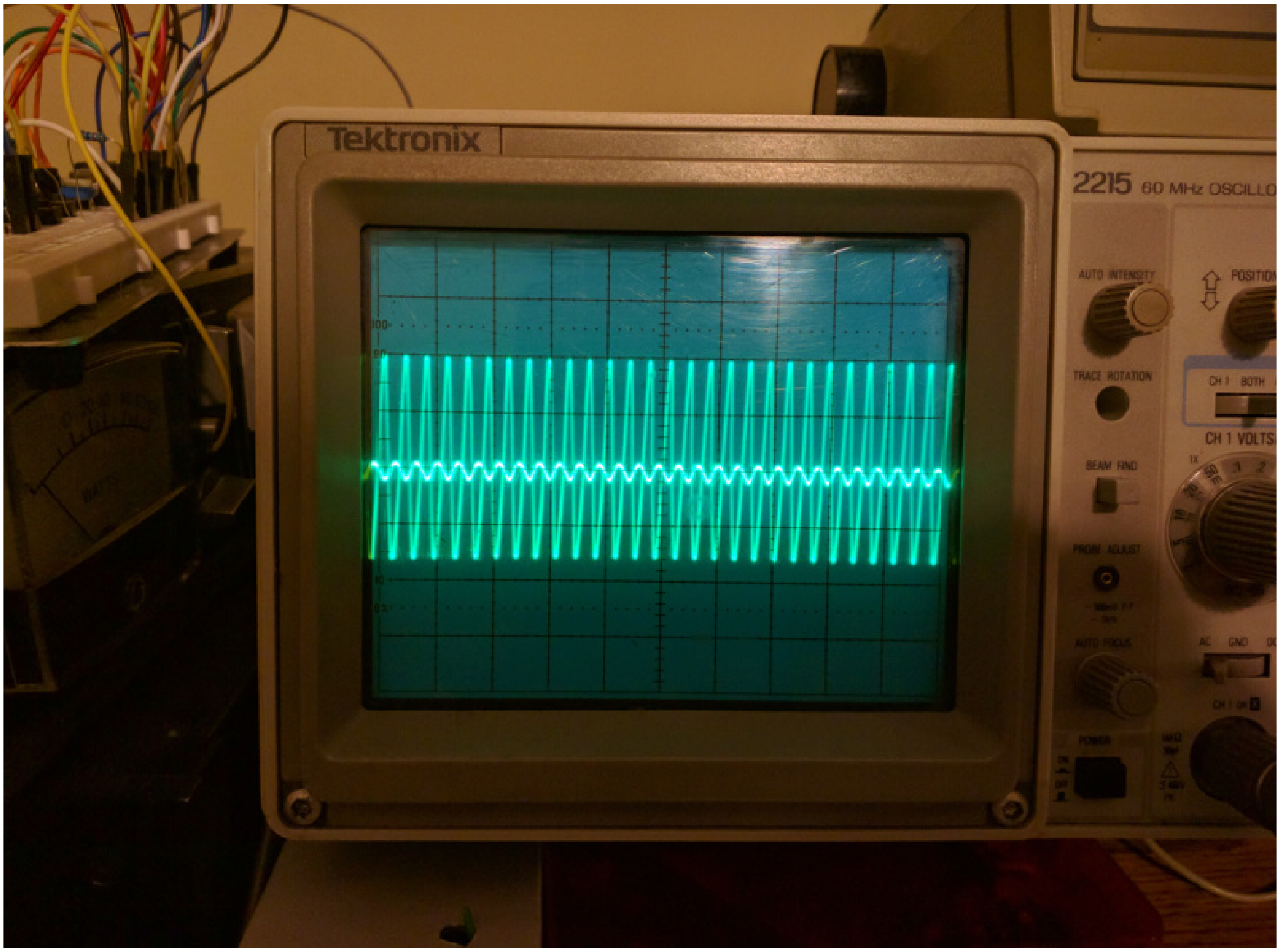

3.3v
5v
12v
12v
-12v
0.06
12.3
FeelTech


IN
OUT
80-20m

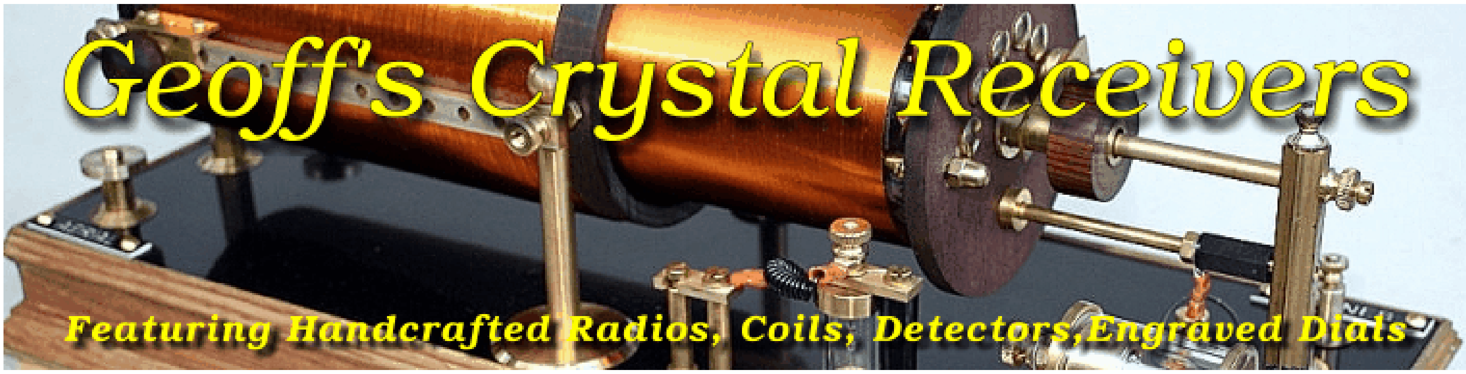

104
104
OUT



With the 2N3904 it works well from 80 meters to 20 meters.



I swapped the 2N3904 for a KSP10 and it works well up into VHF.



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- More Crystal Sets
- Projects

Crystal Radios a Growing Fascination.

Anyone whose visited my Beltane designs site Beltane Products will see I like to make things from raw materials like leather and wood and brass. Mostly functional things with an artistic theme running throughout the design but there is also the scientific side of me that also is bursting for expression.

Since my early youth I had a training in electronics and radio. My workshop has grown with some basic engineering equipment like lathes engraving machine, drill presses and fly presses many hundreds of hand tools all crying out to be used. It seemed a logical step for me to blend both the scientific and the artistic and come up with a different form of expression.

The crystal radio strange as it might seem has a fascination and a satisfaction within my creative ability. Trouble is I've never really made anything for myself in all these years things go out of my workshop to other people. I guess I really enjoy giving and making for others more than keeping things for myself.

These radios have been sold. I can make a custom made radio for you. Please enquire.

Crystal Radio Earth Station Receiver Mk1

Order Nr. *Mk 1 Crystal Radio* (sold)

This was the first radio I made using a home made oak box and engraved Gravoply. I wanted to create a simple but classic look. I used a Calrad Type Vernier dial for slow motion tuning but although it worked well I was not exactly happy with the visual appearance being too modern.

The coil on this set was wound with an AVO Douglas coil winding machine that I renovated. The old AVO's machine was completely worn out when i got it and I had to get a new traverse thread made before it would wind anything resembling a coil. I now wind all my coils from .15mm up to .5 mm wire on this machine for heavier coils I use a modified Lathe.

(See AVO Photo).

The Mk1 set whilst looking ok was prone to the old problem with simple single coil sets of overloading and damped tuning range, it was an interesting experiment though which has lead the way to other projects of a more advanced design.

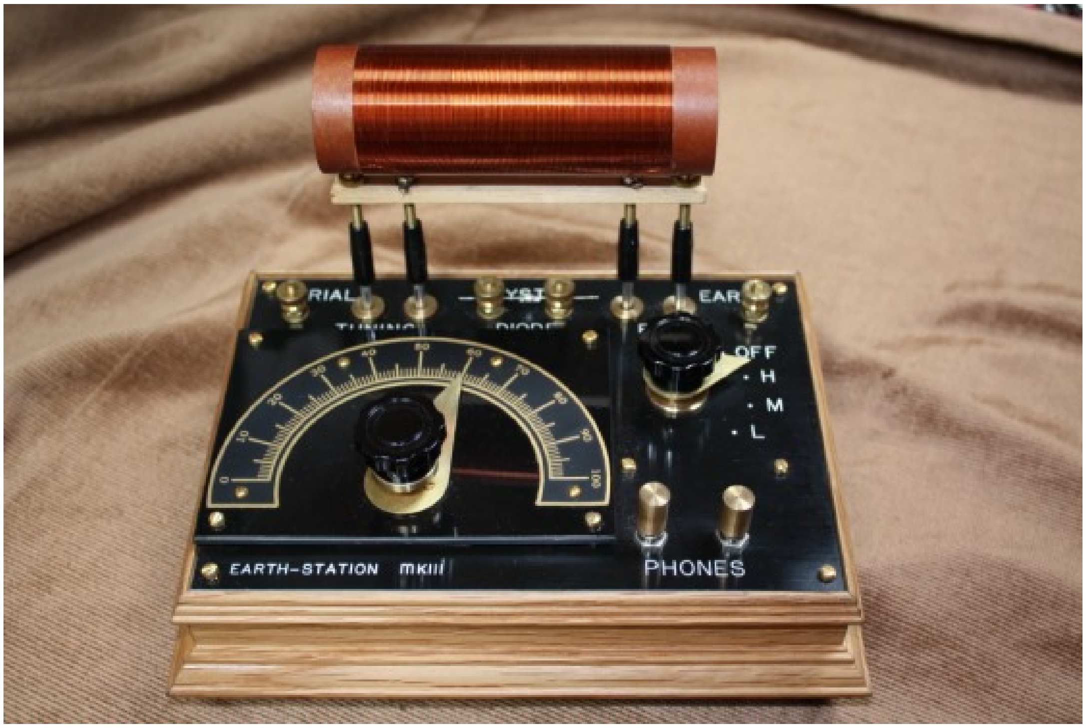
Crystal Radio Earth Station Receiver Mk2

Order Nr. *Mk 2 Crystal Radio* (Sold)

I wanted to extend the limited tuning range of the Mk 1 radio and I added a tapped coil to this radio. I could switch the main inductance from 100- 400 micro henries. I also put on an aerial coupling coil which helped reduce the overloading and damping.

I have wound all the coils I have made so far on 'Paxolin' which is a trade name for a form of Bakelite. It is still one of best insulating material for coils because it is 'Dry' electrically it looks and smells great remember that old radio from the 20's and 30's this was the material that gave it that characteristic smell. It is very hard to find this material today as its not made anymore in large quantities. I was very lucky to find quite a few feet of it from a de-commissioned transmitting station it is Genuine Vintage Tube.

Mystery Crystal Radio Mk3



Order Nr. Mk3 *Mystery Crystal Radio*.(Made for Thomas Fussing)

This set was my first to use all brass fittings. I prefer to use solid brass rather than nickel plate it seems to enhance the look of quality and I can make many of the parts on the lathe to match up all the fittings. I made a plug in coil for medium wave band and I can simply plug in a Long wave or Short wave coils on this set. I did not want to restrict what type of coil design I used ultimately so I can swap over to spider or basket weave coils later to make comparisons with performance.

I made the box from solid oak and finished it with 'Rustins Teak Oil'. I liked the look of the natural oak its grain showed up much better than staining the usual dark brown colour of vintage oak boxes. I always enjoy listening on these projects when they're finished it gives me a sense of satisfaction hearing as well as seeing the end results.

This set has a Bogen type T725 Transformer to change the output impedance from High to low to match whatever phones I have around the workshop and to also see how they compare for sound level and quality.

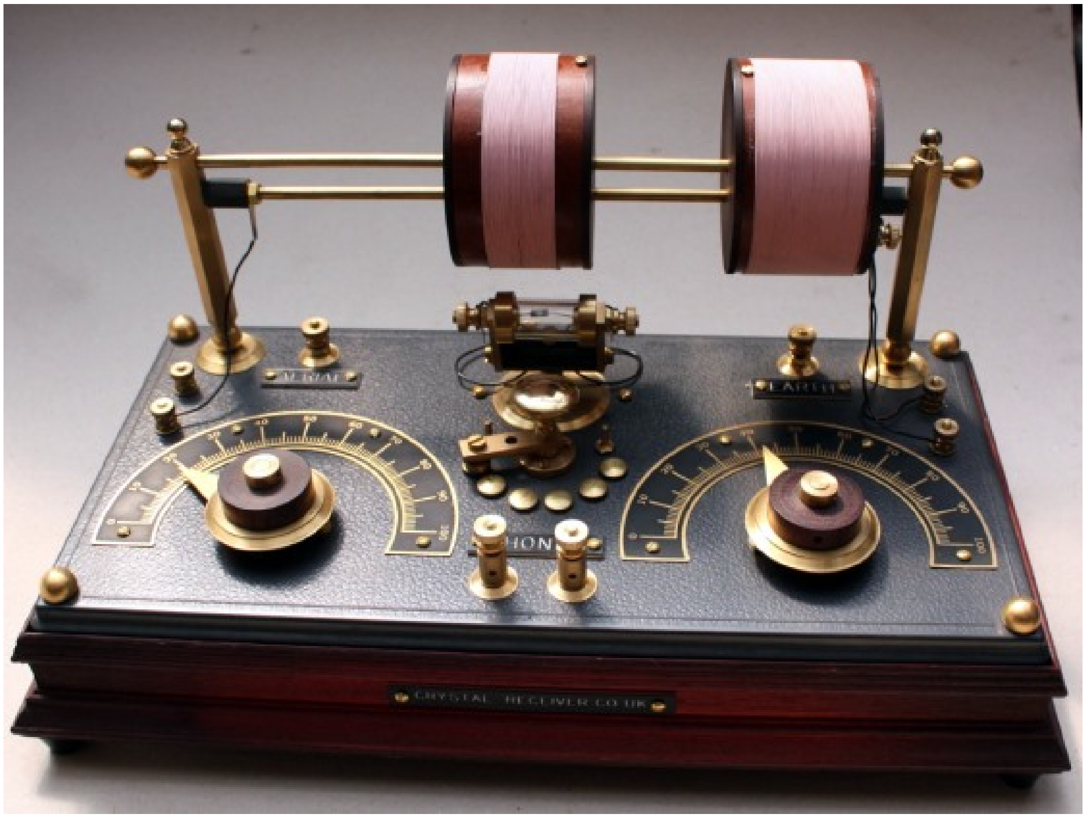
Crystal Radio Mystery Receiver Mk4

Order Nr. *Mystery Receiver Mk4*

Mk4 Medium Wave 'Mystery Coil' Radio with Built in Antenna Tuner and Output Matching Transformer. All Engraved Legends and Mitred Solid Oak Base.

Works Great and is selective. Was a nice project.

Jules Verne

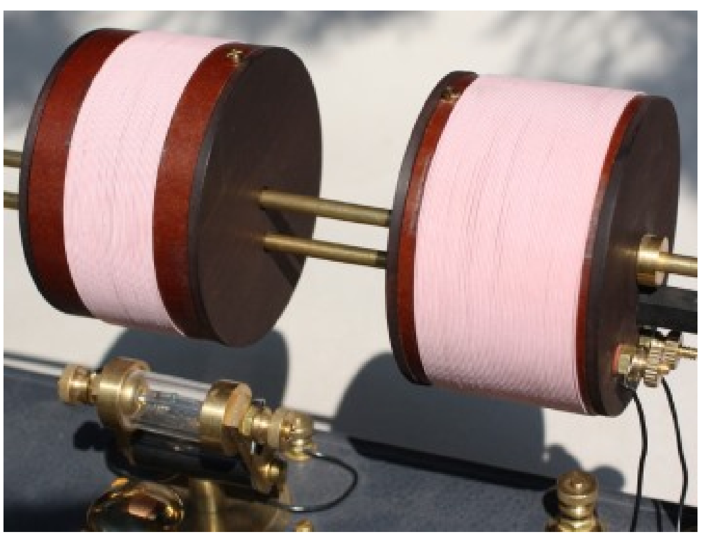


Order Nr. *Jules Verne*

I have decided to call this the Jules Verne set. Did you ever see the film '20000 Leagues Under the Sea'? This reminds me in some way like the inside of Captain Nimos Nautilus submarine with all its brass dials. There is enough Naval brass on this set to sink a Battleship!!

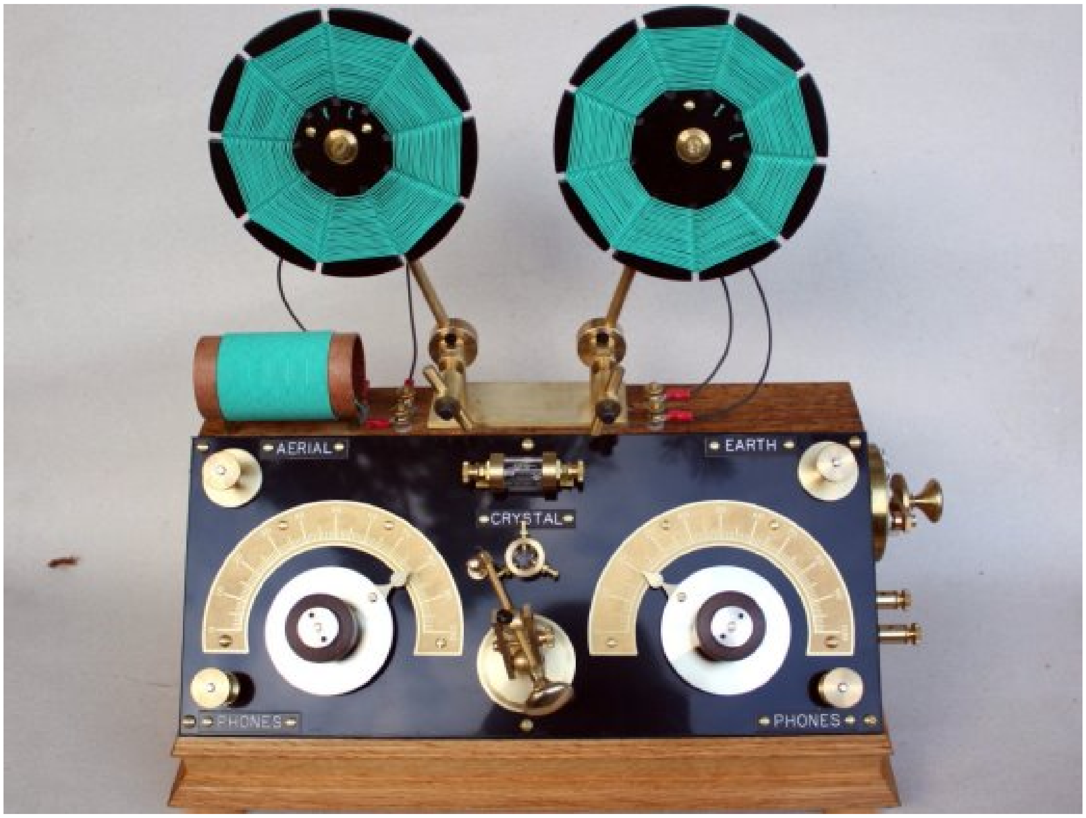
This set has Aerial tuner built in plus adjustable impedance output for any phones from 8 ohms to 5 K ohms.

The Aerial tuner coil can slide along the twin brass rail to get a closer coupling to the main tuning coil . I used a Beryllium Copper spring to make contact with the rails and it worked out well with smooth travel. I have based this design on Dave Schmarder's #70 set. I built this set for Alan Thomas.



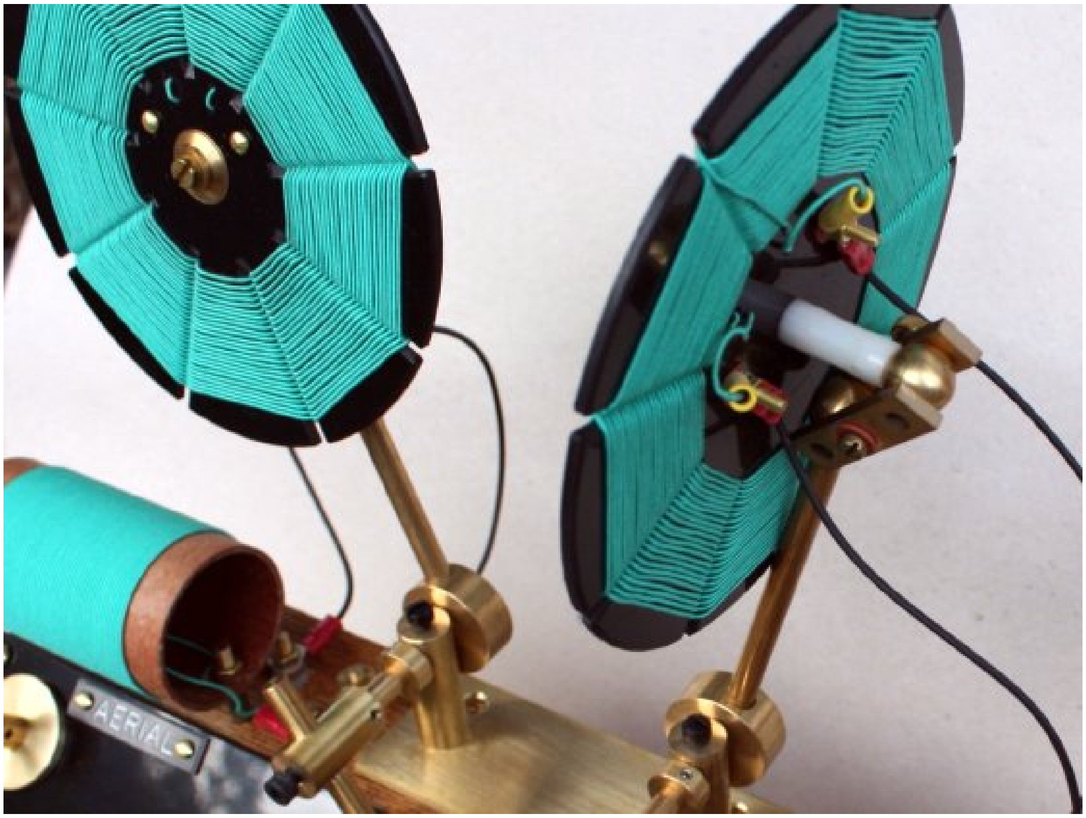
HG Wells 'Time Machine Crystal Radio'

Please click on the photographs for a larger picture of this beautiful wireless receiver.



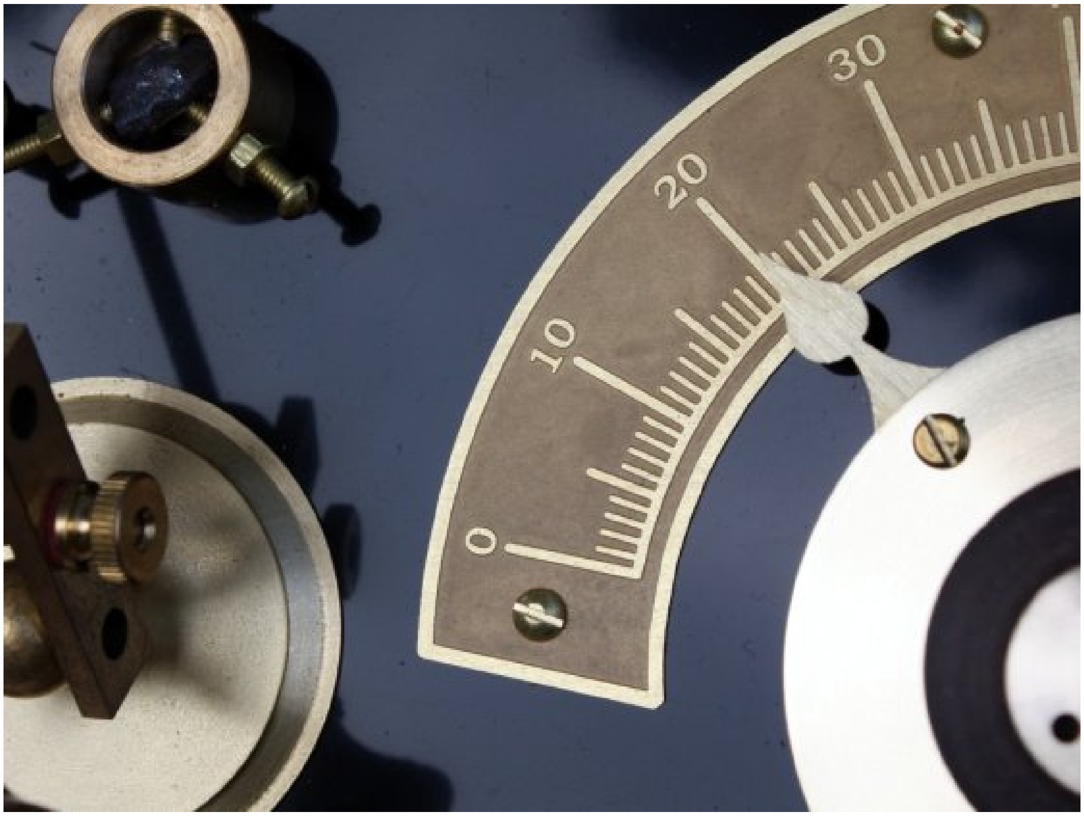
Order Nr. *HGW-1*

I based the circuit design of 'The Time Machine Radio' on my good friend Dave Schmarder's #20 set http://makearadio.com/crystal/20.php The Spider web coils on this radio are the all important heart of the radio and have a very high Q which is what we are really looking for to get the best selectivity and sensitivity from these simple radios.



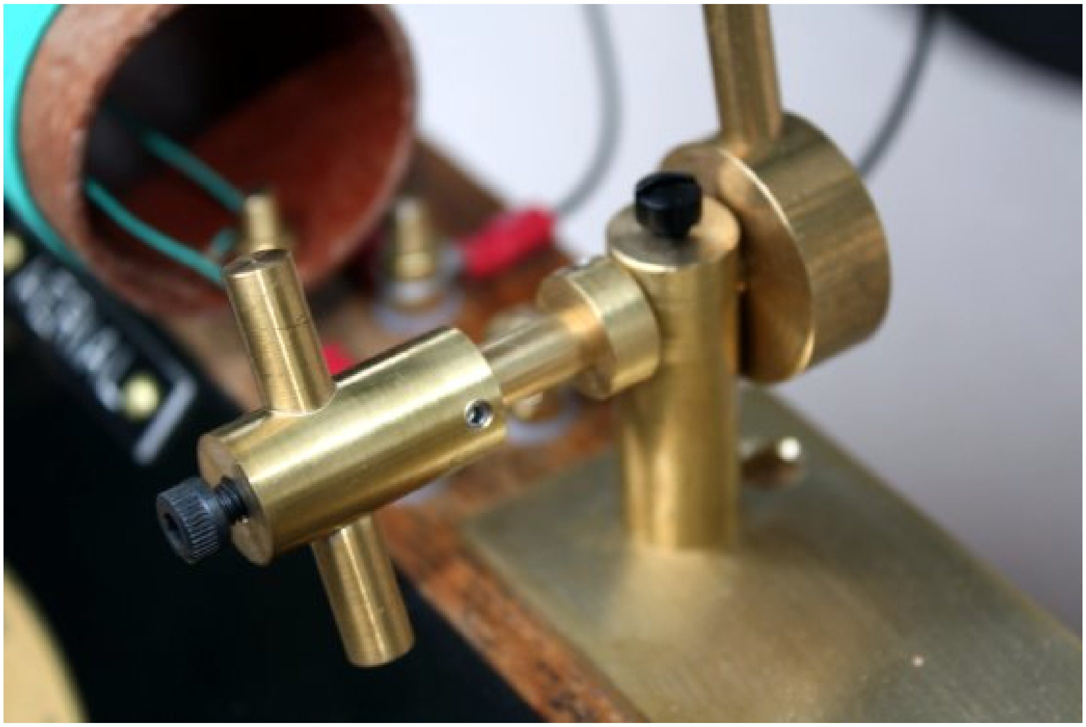
To get the spacing correct I used my Myford lathe and a slitting saw blade mounted in the chuck. I turned the circular disc of HDPE by 40 degree on each cut which gave a total of 9 segments. This type of coil has to have an odd number of segments so that the winding does not end up at the same starting point. 9 segments seem to be the smallest number which make a tidy winding but any odd number ie 11 13 or 15 segments could be used.

The wire I used on this set was 220/46 Litz wire. This is 220 strands of number 46 gauge wire. Each strand of this wire is thinner than a human hair. The wire is also double silk covered.



I hand cut the dial pointer with a jewelers piercing saw from 22g brass sheet. This was screw fixed to main dial plate .Its the fine finishing touches that make this radio one of my more enjoyable projects.

I wanted to keep the two main Litz coils the same size physically which meant I had to add the extra inductance on a series coil. Also shown here is the Aerial terminal and its label. All labels were made on my Pantograph engraver using Gravoply professional engraving material. These are deeply engraved and can never wear off like dry transfer lettering.

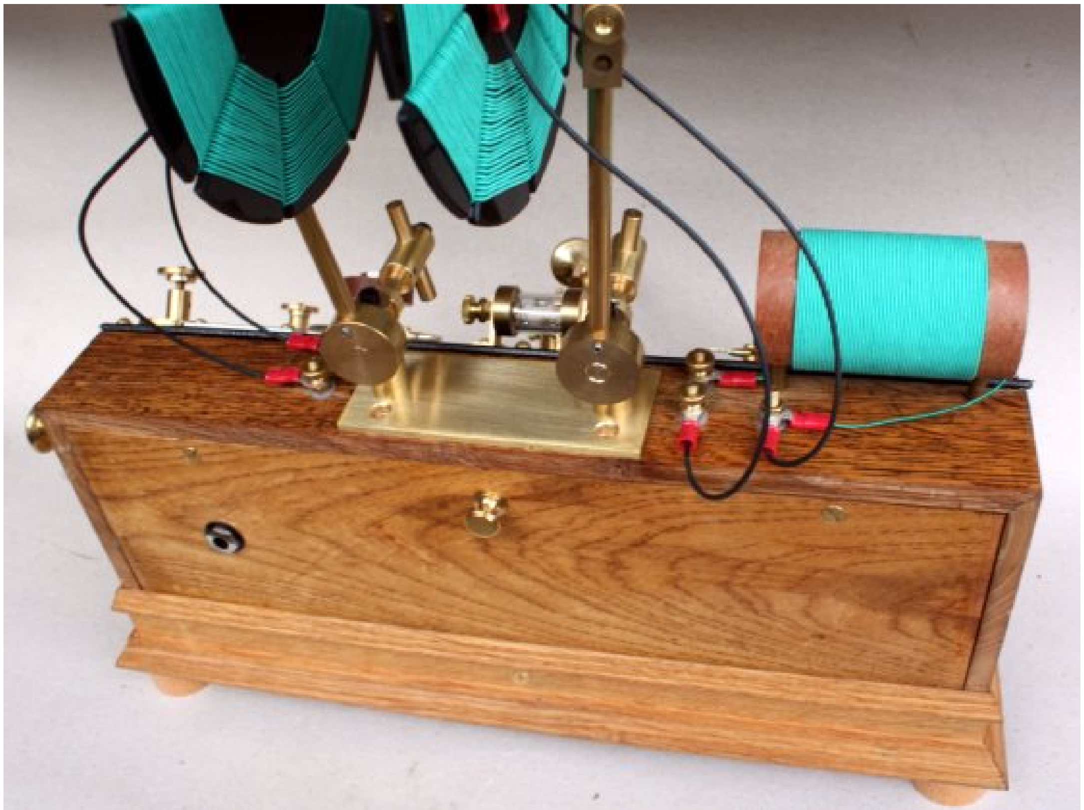


I wanted to make the coils rotate on all axis so I could adjust the coupling in a number of ways, ie facing each other or at any angle to the horizontal or vertical. To do this I made a universal ball joint coupler for each coil. This was fixed to a brass shaft and connected to the handle adjusters on the base plate. Turning the handle would move the coils from the horizontal position to the vertical . I found that the best coupling was when the coils were facing each other and about 3 inches apart but I noticed that if coils were placed at ninety degrees to each other I was able to null out some adjacent stations or interference. When coils were facing forward the set performed with much less over coupling for closer coil spacing. If coils were facing each other and less than 3 inches apart the set would become very over coupled and all stations would interfere with each other and the tuning became very broad.

This set has a Bogen T725 Transformer to match the headphones. Any phones can be used from High Impedance 4K ohms or down to 8 ohm types.

The selector switch was fabricated from brass 'Chicago studs' for the contacts these were insulated from the body of the switch with Nylon transistor mounting spacers as used on a type 2N3055 to mount to the headtsink The knob was from my local DIY store and was intended for a cupboard draw but I recoin it looked great on the switch. The switch is spring loaded internally so that it makes a good contact on each stud.

This was a nice little engineering project on its own and I will be using this design on many more of my radios.



On the Back of the Radio is access door to the wiring. Note the little brass turned knob. The 8 ohm headphone socket is mounted on the rear of the box.

The lovely grain of the Natural Oak wood shows up best on the back of the radio. I didn't stain the wood finish on this radio it was just lightly oiled with Linseed oil which really brings out the grain detail.

Geoff's Crystal Sets, Page 2

**Aerial Parts | Brass Hardware | Capacitors | Coils | Detectors | Diodes
Engraved | Links | Loose Coupler | Misc. Items | Projects | Radios |Radios-2
Radios-3 | Switches | Workshop**

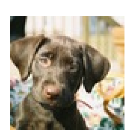

(https://cdn.instructables.com/F4F/52SG/GJQE8LQ1/F4F52SGGJQE8LQ1.MEDIUM.jpg)

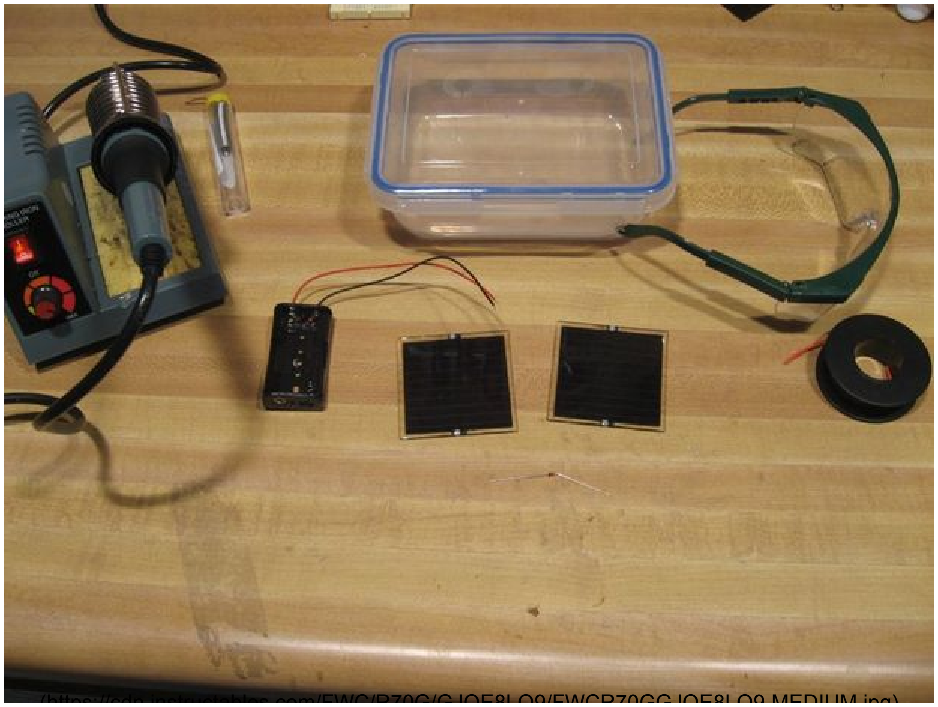
When I got into electrical circuits and solar power, the first thing I wanted to do was build a little solar powered battery charger. Only I had a heck of a time trying to find a simple and straight forward guide to doing this.

So in this guide I'll give you a bit of info on solar power and battery charging, as well as show you how to make a solar battery charger for all of $4.

If you'd like some solar panels or solar kits I have quite a few on my gadget site, browndoggadgets.com (http://browndoggadgets.com) or you can also buy them off ebay or various other websites.

Step 1: What You Need


BrownDogGadgets (/member/BrownDogGadgets/)
BrownDogGadgets (http://www.browndoggadgets.com)
(/member/BrownDogGadgets/)
Follow 1936



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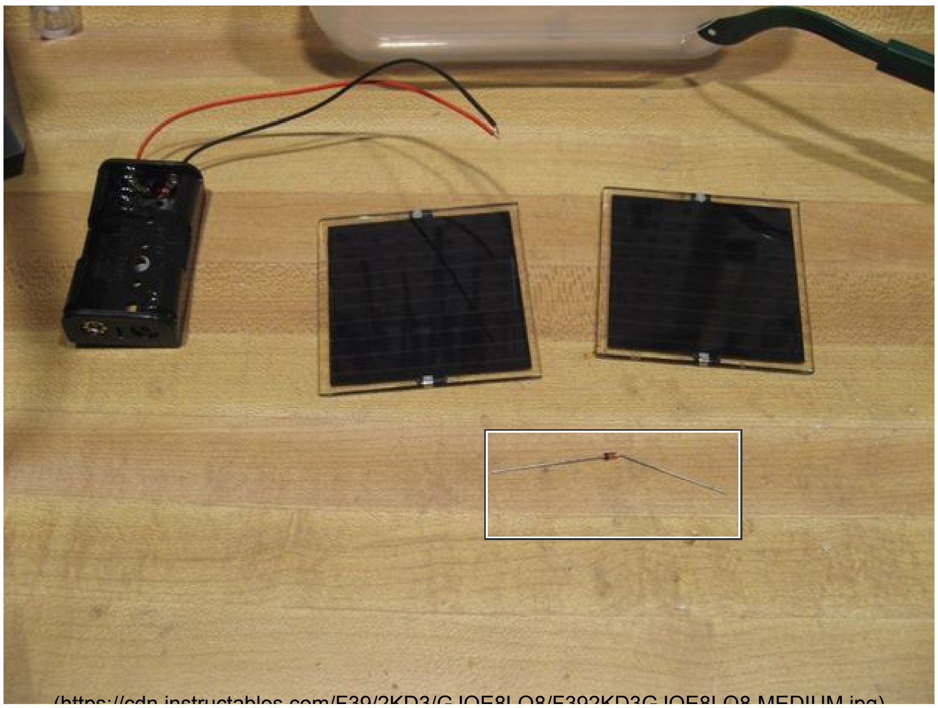


(https://cdn.instructables.com/F39/2KD3/GJOF8LQ8/F392KD3GJOF8LQ8.MEDIUM.jpg)

Bio: I used to teach middle school science, but now I run my own online educational science website. I spend my days designing new projects for ... More » (/member/BrownDogGadgets/)

More by BrownDogGadgets:

To build a solar battery charger you need several things, as well as have several tools on hand.

Parts
A clear, water-proof container. (Dollar Store tupperware with built in O-Ring)
AA Battery Holder (http://www.browndoggadgets.com/products/aa-battery-holder-double) (Radio Shack, also fits AAAs if you're careful)
One or Two Solar Panels (http://www.browndoggadgets.com/collections/solar-cell) rated 4 Volts or above
Blocking Diode (http://www.browndoggadgets.com/collections/diodes)
Tools you need
Soldering Iron
Solder
Tape

Safety Goggles
Some wire

Time: 20-30 minutes

Difficulty: Easy

Step 2: Things You Should Know

Solar Power is fun, and adding solar to your projects is even more fun. Plus these days it's darned cheap to do.

When making a battery charger there are things you should keep in mind.

First, know your batteries. NiMh batteries are the most common these days, and you can find them at any store. Your typical AA NiMh battery probably is 1.2 Volts and has anywhere between 2000- 3000 mah worth of charge in it. (Check your batteries, they probably have the capacity written on them. That or check the maker's webpage.)

Secondly you need to know your solar panels. For instance, the ones I'm using in this project put out a max of 4.5 volts and 80 ma of charge.

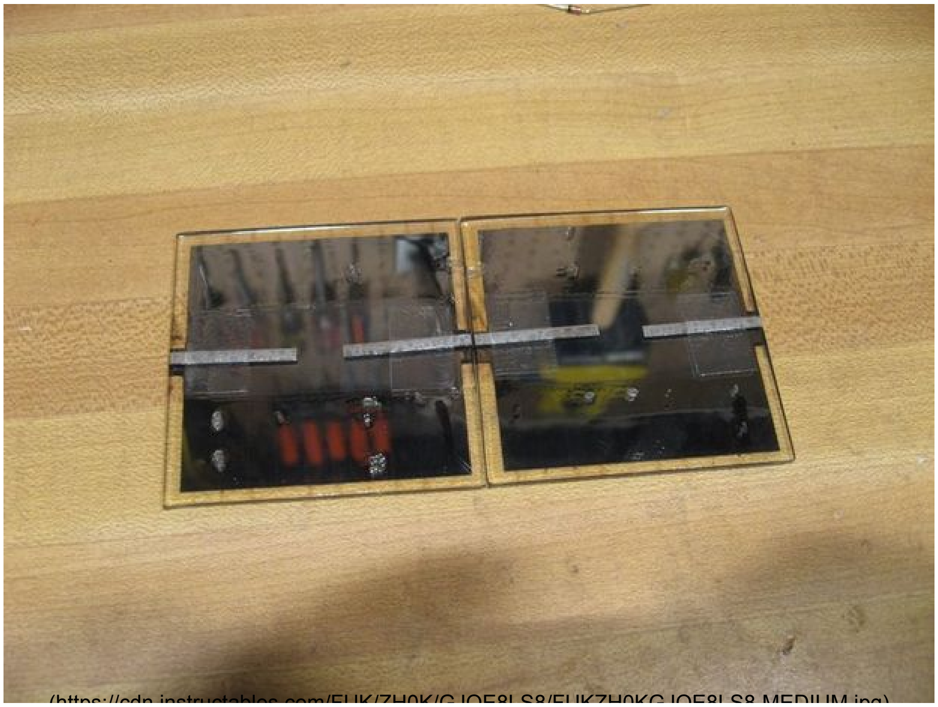
With only 4.5 volts coming in, I really shouldn't try charging up any more than two batteries (hooked up in a series giving me 2.4 volts). Also, because one of my solar panels only puts out 80 ma at a max, it's going to take a long time to charge up all 3000 mah hours my batteries hold. In this guide I hooked up two panels in parallel to give me around 160 mahs worth of power coming in. If I had a bigger case I could hook up another one or two to give me even more power.

You're probably asking yourself, "hey, why doesn't he hook up a whole lot of panels to throw down a massive amount of amps and fast charge those batteries!" Good point, but if I did that I'd kill the batteries. Your standard wall charger has brains that let it fast charge a battery without blowing it up. We're going about our charging using the "trickle" method. As a general rule of thumb, you don't want to throw more than 10% of the capacity of the battery (C/10) at the battery when charging. As our batteries are 3000 mah capacity, and we're throwing 160 mah of charge at it, we're ok. (AAA batteries hold between 800 -1800 mah, so we're probably ok for them as well as we're never going to actually get the full 160 ma from the cells.)

If you really want to charge up your batteries fast, you could try and hit the C/10 power supply. Though this being solar, it would still take a while.

So there you have it. Now you've got a basic idea of how to add solar power to your projects. Now go out and buy some Solar Panels and NiMh batteries.

Step 3: Panel Power



(https://cdn.instructables.com/FUK/ZH0K/GJOE8LS8/FUKZH0KGJOE8LS8.MEDIUM.jpg)

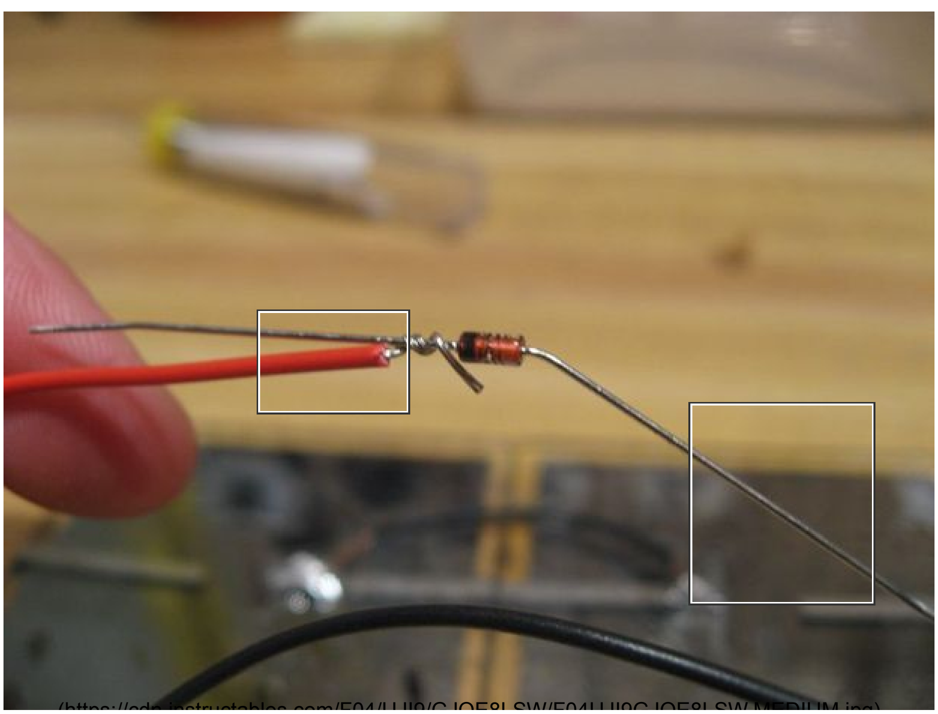
I love these 4.5 volt panels. I use them for most all of my solar projects. They're small, light weight, strong, and throw out a lot of power.

Because my solar panels have little tabs on them, I'm going to need to do some extra soldering and taping that you might not need to do with your solar panels.

That being said, no matter what kind of solar panel setup you're using, you'll want to be wiring them up the same way.

(For instance you could use a smaller panel to charge up a single AA battery, or a bunch of panels in a series to charge up a whole bunch of batteries at once.)

Step 4: Blocking Diode



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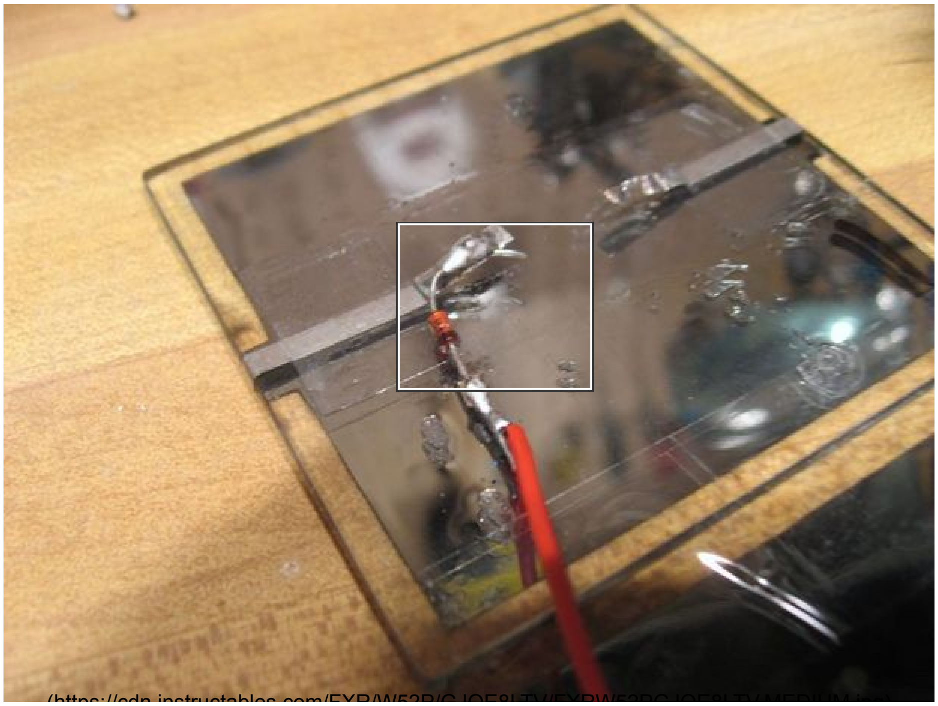

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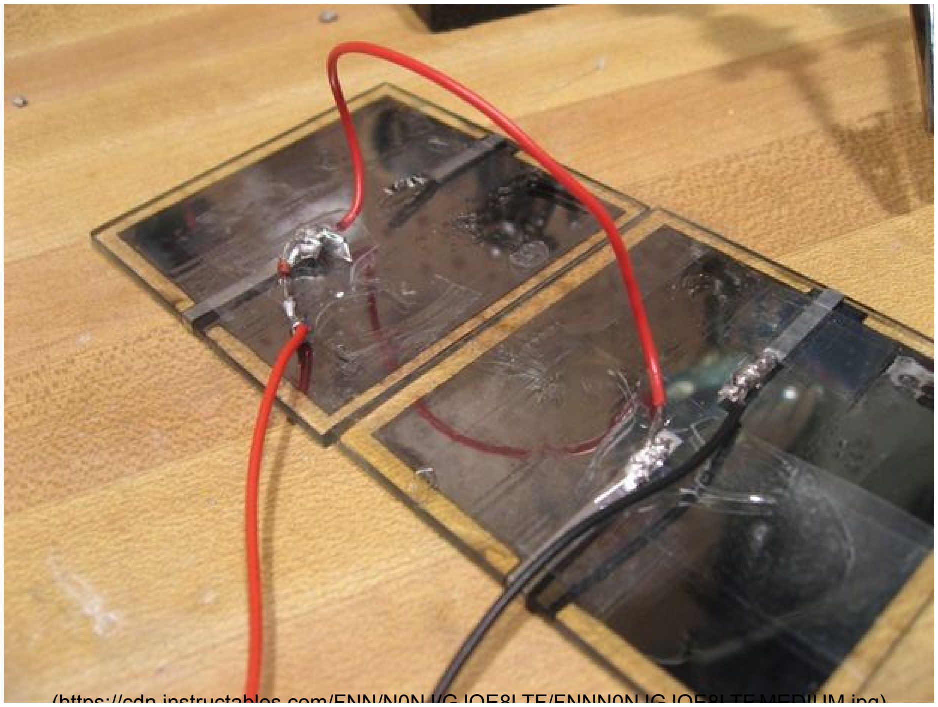
The first thing I'm going to do is hook up my blocking diode. I just soldered it onto the positive wire coming off my battery holder, and then the other end of the diode onto one of the positive tabs on a solar panel. Also, at this time, solder the negative wire from the battery pack onto one of the negative tabs of the solar panels.

(If you're only using one solar panel, you're actually done with soldering.)

Why do we need this? Well, solar panels are great at creating power when it's sunny out. When it gets dark, they try and suck power back into themselves, which then destroys them. To stop this we use a blocking diode so that power only flows in one direction.

Also, see that black bar on the diode. Always make sure you know which way it's going. You want the black bar pointing in the direction you want power to flow.

Step 5: Strength in Numbers



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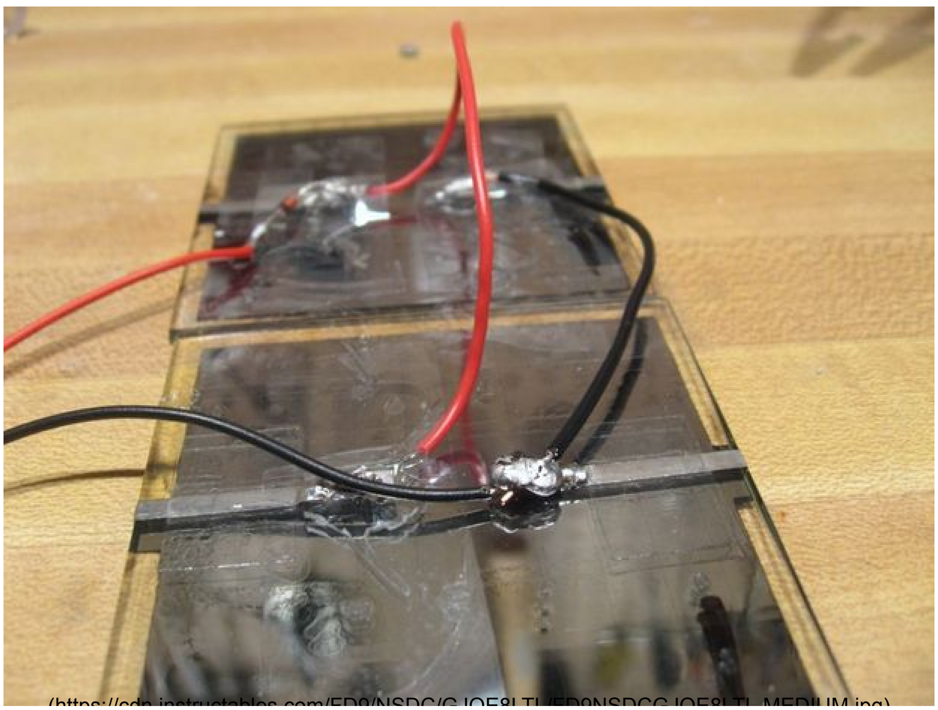


(https://cdn.instructables.com/FD9/NSDC/GJOE8LTI/FD9NSDCGJOE8LTI.MEDIUM.jpg)

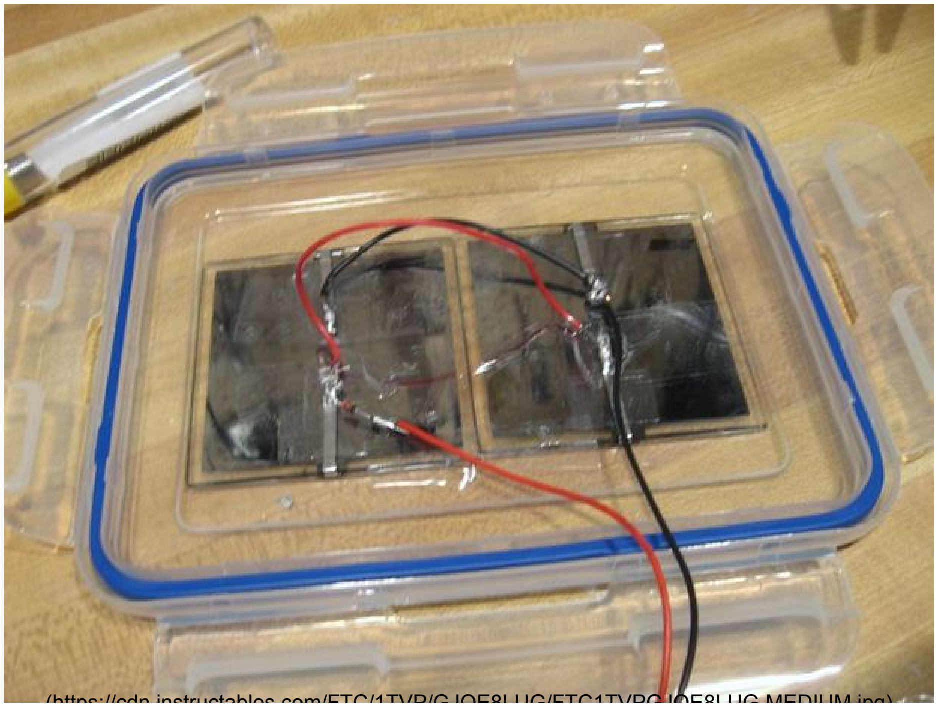
Ok, so if we only had one panel we'd be done now. Since we're using two panels hooked up in parallel we have a bit more soldering to do.

To hook them up in parallel we're going to use two more wires to connect both positive tabs and both negative tabs.

Cut two wires at about the right length for a bridge and solder.

Remember, we're hooking positive to positive, and negative to negative.

Step 6: Lots of Tape



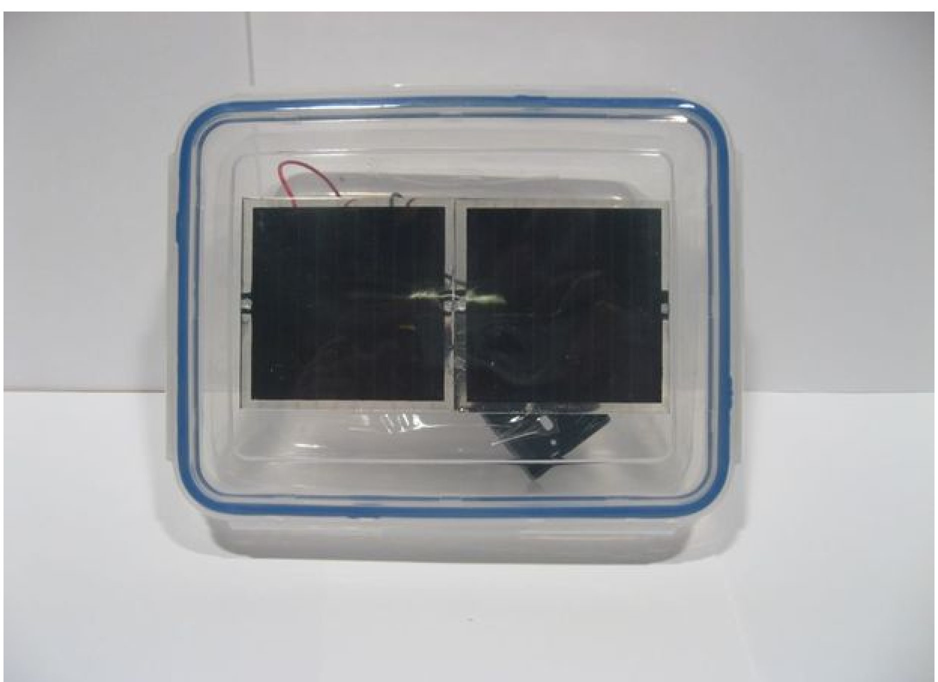
(https://cdn.instructables.com/FTC/1TVR/GJOE8LUG/FTC1TVRGJOE8LUG.MEDIUM.jpg)

While all my soldering is done it's painfully obvious that my little solar panel tabs look like they're ready to break off. For good measure I always put some tape over the solder points on my solar panel, especially panels with little tabs on them.

Then just tape the panels into the lid of your enclosure. That was easy.

For my enclosure I used a little tupperware thing I got from a local Dollar Store. It has a freshness o-ring in it that keeps moisture in, which also means it'll keep moisture out. Handy for projects you want to leave outside for long periods of time.

Step 7: Enjoy



(https://cdn.instructables.com/FBR/OXDA/GJOE8LUR/FBROXDAGJOE8LUR.MEDIUM.jpg)

That was easy. I've done this a couple of times before and at this point building one takes me under 20 minutes.

So the breakdown is this.

Cost: $4

$1 Tupperware
$2 Solar Panels
$1 Battery holder
$0.02 Blocking Diode

Time: 20 minutes.

You can use this EXACT same setup to power little light up projects. Throw in a few transistors and resistors and you can make a dark detecting circuit for all of $0.20 more.

If you're looking for solar panels or little solar kits I have several available on my website browndoggadgets.com (http://www.browndoggadgets.com).

Comments

naturefreak (/member/naturefreak/) 2011-12-26 Reply

Will a small led work as a blocking diode ?

RobC166 (/member/RobC166/) ▸ naturefreak (/member/naturefreak/) Reply

2017-06-23

As long as you dont overload the LED depends on the power of the panels.

yhdesai (/member/yhdesai/) ▸ naturefreak (/member/naturefreak/) Reply 2014-12-17

yes

badlandsghost (/member/badlandsghost/) 2015-05-15 Reply

Great idea, you mentioned the dark detecting circuit, how would you work that in? It would be perfect for some Halloween led "eyes" i built a few years back. Thanks again

RobC166 (/member/RobC166/) ▸ badlandsghost (/member/badlandsghost/) Reply 2017-06-23

effectively you would require two seperate circuits that overlap at the battery.. One to recharge the battery and the other using the battery as a source.

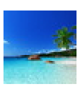
Hydon (/member/Hydon/) 2016-03-04 Reply

Hi,

Nice build you made! I want to make my own now aswell. I have a question, what will happen if there is no battery hooked up? Will this destroy the cells?

RobC166 (/member/RobC166/) ▸ Hydon (/member/Hydon/) 2017-06-23 Reply

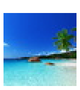
It shouldn't as the circuit wiill remain open with-out batteries.



haselot (/member/haselot/) 2017-01-09 Reply

We can recondition old batteries http://ezbatteriesreconditioning.com (http://ezbatteriesreconditioning.com)

Thank you Gregory ! :)



haselot (/member/haselot/) 2017-01-09 Reply

We can recondition old batteries http://ezbatteriesreconditioning.com (http://ezbatteriesreconditioning.com/)

Thank you Gregory ! :)

Chastmartin (/member/Chastmartin/) 2016-12-05 Reply

Have 2 solar panel each 5v at 1.2A. Want to charge 3v batteries. Possible?

RyanC168 (/member/RyanC168/) 2016-06-12 Reply

I have been struggling with this forever. All I want to do is use my 5v panel to charge my 1.5v NiHM triple A batteries. Seems like it kills every battery, they start out low at 1.0V and then after I use the panel with + to + - to -, with a diode on the negative lead.

What am I doing wrong?

alexlfm (/member/alexlfm/) ▸ RyanC168 (/member/RyanC168/) 2016-06-14 Reply

First of all, the blocking diode usually goes on the positive terminal of the solar panel going towards the batteries. Secondly, you are using multiple batteries correct? I completely disagree with this article, if you have a 4.5v panel you need to have 3 batteries connected in series to charge safely since each battery is 1.35v charged. With only two batteries on a 4.5v panel you are putting too much voltage on the batteries 4.5v on 2.6v max of batteries, and risk damaging them, especially long term. Over voltage destroys batteries. This is why most solar lights have 1.5v, or if they use two batteries 3v, panels.

alexlfm (/member/alexlfm/) ▸ alexlfm (/member/alexlfm/) 2016-06-14 Reply

Sorry I missed that you have a 5v panel. In this case you may want to use either 4 batteries (which would never get fully charged but would come pretty close at 1.25v) or else consider using a resistor with at least 2 batteries. Remember R=V/I from physics? If you need a refresher see this page here: http://www.gtsparkplugs.com/Dropping_Resistor_Calc.html You do need to be careful though since the more voltage you are dropping, the higher the wattage resistor you need (in general, most resistors are 1/4 of a watt. For one battery ideally shoot for a voltage of 1.5, 3v for 2 batteries, 4.5 for 3 6 for 4, and so on.

RyanC168 (/member/RyanC168/) ▸ alexlfm (/member/alexlfm/) 2016-06-14 Reply

Ok, also if I stepped the volts from 4v5. to 3.6 v to charge 2 batts or something like that, could I get more mA current, charging the battery faster?

RyanC168 (/member/RyanC168/) ▸ alexlfm (/member/alexlfm/) 2016-06-14 Reply

Ok, I have a 4.5V Panel at 200mA, about 1W, and I only had 2 NiMH triple A's connected for charging.

I realized I did the diode on the wrong side, but was confused because I guess the Positive side of the battery actually has the most Negatively charged particles (sigh..lol) so everything I read prior about current flow direction was misleading to the project.

Soo, I set the diode on the pos terminal of the panel facing toward the battery pack (I guess about 2.5-2.7v) and It didn't die, but didn't seem to charge after a couple hours in the sun.

Is there a way to directly check if the current is flowing into the batterie's + terminal?

alexlfm (/member/alexlfm/) ▸ RyanC168 (/member/RyanC168/) 2016-06-14 Reply

I would first make sure that you have the diode the right way round. Diodes do obviously only go in one direction and have a set polarity. The line on the diode always indicates the negative (out) end.

The easiest way to check is to put a multimeter, set to the ma current range and then connect it in series between the diode and the battery pack with the red positive probe on the diode out side and the black negative probe going to the battery pack. The meter will read a positive reading in mA if everything is working correctly, which is how much power is flowing into the batteries. If you don't have a multimeter I would highly suggest getting one as it's really an essential tool and worth it just for checking batteries and basic repair/automotive uses; For basic dc, low voltage, use, they can be found quite cheaply at around $7 (I can recommend some if you don't have one). You can also short circuit the solar panel through a multimeter with just the diode and nothing else attached to it to get an idea of it's performance. Solar panels are one of the few things it's fine to short circuit. Unfortunately apart from a multimeter the only thing I can suggest is connecting an LED temporarily in series before the battery packs just to see if the panel is producing power (though if you leave the LED in it will burn out without a properly sized resistor).

The other thing to keep in mind is that solar panels in general, although especially these smaller ones, are very sensitive to the angle of the sun and the output can go from maybe 100mA or possibly less laying flat on the ground to 200mA angled into the sun. This site has lots of detail on solar panel angles (and the effect on output) and was very helpful to me: http://www.solarpaneltilt.com/ (http://www.solarpaneltilt.com/)

corbinearl (/member/corbinearl/) 2013-07-12 Reply

where's the best place to find the solar panels? I'm sorry if someone asked this and I didn't see it when I looked

mrvhappy (/member/mrvhappy/) ▸ corbinearl (/member/corbinearl/) Reply 2015-06-09

Hi,

Great idea, but your $4 build figure doesn't add up.

On your website you are selling the..1V 500mA Solar Cells for $8.99!!..so how can you build it for $4?

Sorry I dont mean to be negative, but this fact appears to have been "over looked"

I look forward to your comments.

Regards

Benferb12 (/member/Benferb12/) ▸ mrvhappy (/member/mrvhappy/) Reply 2015-06-24

What I did was got 2 little solor toys from the dollar store and hacked off the panels

RyanC168 (/member/RyanC168/) ▸ Benferb12 (/member/Benferb12/) Reply 2016-06-12

Yep me too

GeertV8 (/member/GeertV8/) 2016-02-06 Reply

How would I hook up a battery and a charge, like the pump with panel with battery below? Should I put a diode at the solare panel and a zener diode towards the battery?

http://www.amazon.co.uk/gp/product/B007IS4B4S/ref=...
(http://www.amazon.co.uk/gp/product/B007IS4B4S/ref=s9_dcbhz_bw_g86_i3_sh)

mpeterson19 (/member/mpeterson19/) 2013-12-03 Reply

Could a charge controller be placed somewhere between the solar panels and the batteries? And can the batteries be charged while they are also powering a small device?

mrvhappy (/member/mrvhappy/) ▸ mpeterson19 (/member/mpeterson19/) 2015-06-09 Reply

In theory, you have the right idea, however as these solar panels product such a small amount of current.voltage, I am not sure if it would be worth it.

If you had a larger panel producing more power, say a 12v / 2.5W+ then you could connect this to acharge controller and car battery/inverter setup...

mrvhappy (/member/mrvhappy/) 2015-06-09 Reply

Hi,

Great idea, but your $4 build figure doesn't add up.

On your website you are selling the..1V 500mA Solar Cells for $8.99!!..so how can you build it for $4?

Sorry I dont mean to be negative, but this fact appears to have been "over looked"

I look forward to your comments.

Regards

SamW8 (/member/SamW8/) 2015-05-20 Reply

Works very well.

Thanks.<img src="http://s04.flagcounter.com/mini/kfoW/bg_FFFFFF/txt_DEDEDE/border_F7F7F7/flags_1.jpg" style="display:none">

716Thornapple (/member/716Thornapple/) 2015-05-08 Reply

I would like to know too.

motse.baikitse (/member/motse.baikitse/) 2015-03-13 Reply

vuralzone (/member/vuralzone/) 2014-06-20 Reply

Nice job !!

But I have question, do we really need the blocking diode?

As far as I know, solar panels have almost the same physical structure with diodes and they don't allow back current.

Could you correct me please

Thanks

JaredD1 (/member/JaredD1/) ▸ vuralzone (/member/vuralzone/) 2015-02-25 Reply

Solar panels do allow back current.

iratozer (/member/iratozer/) 2015-01-02 Reply

What would be required to run a laptop computer?

JaredD1 (/member/JaredD1/) ▸ iratozer (/member/iratozer/) 2015-02-25 Reply

You would need a much bigger solar panel (~15v and at least 60 watts) and good size car battery plus a 12v DC to AC 120v inverter, to plug in your AC laptop adapter.

SparkySolar (/member/SparkySolar/) 2014-10-18 Reply

so simple

rishichavda (/member/rishichavda/) 2014-07-06 Reply

Very nice project, could have made it very smaller and thus more portable/convenient. Great make overall, hopefully make my own in the next few days/weeks.

kolotour (/member/kolotour/) 2014-01-15 Reply

Hey boys and girls, here's a source for some cheap solar battery chargers. Used solar powered yard lights. These ARE solar powered battery chargers already along with a circuit to turn the light on when it's dark. Folks toss these things when they stop working. Usually it's the battery that dies or corrosion that causes the failure. Many end up at your local 2nd hand store. Maybe 50 cents or less for each one. Insert a new battery and/or clean up the contacts and pull out the LED bulb you're done. They're inexpensive when new too. $2 - 4 bucks each.

conscious (/member/conscious/) 2013-12-26 Reply

Hey, kids. Here are some electricity basics. mAh (milliAmpere-hour), a unit of charge and mA (milliAmpere), a unit of current (charge per unit time) are not the same thing. A 3000 mAh battery would run, in principle, for 30 hours if a constant current of 100 mA is drawn from it, for example.

Jobo17 (/member/Jobo17/) 2013-12-05 Reply

I can't get over this charger, it's just "different" from the others, this is what got me wanting to make one, so whenever I pass by this when looking for a good design (which I'll probably just end up making my own), I just always click on it

and look at it again and just see how simple it really is

P.S. My Algebra teacher in 8th grade had a last name of Zimmerman, so I always think of him when I see yours

Jobo17 (/member/Jobo17/) 2013-12-05 Reply

mpeterson19, I can't tell if you mean on/off switch or have the electricity go one way? If your talking about direction then use a diode inbetween the panel and the circuitry (so it goes panel, wire, diode, wire, circuit stuff). If you're talking about on/off switch for charging then you would put an on/off switch between circuit and output or between panel circuit (in order)

JCG5 (/member/JCG5/) 2013-11-16 Reply

Where did you get the solar panels from?

Jobo17 (/member/Jobo17/) 2013-08-15 Reply

AndroidJack... it's the mA... the panel's mA shouldn't exceed 10% of the mA capacity of the battery...(theoretically)... the panel usual doesn't get what it says when it comes to mA so you have a little wiggle room.

AndroidJack (/member/AndroidJack/) 2013-07-07 Reply

Awesome build!

This really got me thinking, so I visited browndoggadgets.com for even more ideas. I have two 5V 100mA solar panels already that I want to use, but my question is what determines the rate at which the batteries charge? Is it the difference between the mA from the panels and the mA capacity of the batteries, is it something to do with the voltage, or is it a combination of both, and if so how exactly?

RandomIdeaMan (/member/RandomIdeaMan/) 2013-07-03 Reply

Great Instructable.

Just wondering how much the voltage of the solar cells matters? You went into depth about the amps, but only mentioned that your cells run at 4v.
Does the voltage need to be higher than the battery supply?

Also what happens if you do leave them to charge for months? I have some ideas for projects, but they would be sitting outside for a long time...

AndroidJack (/member/AndroidJack/) ▸ RandomIdeaMan (/member/RandomIdeaMan/) 2013-07-07 Reply

Yes, the charge voltage must exceed the total full-charge voltage of the batteries.

As long as you have your diode properly in place, keeping this setup out for a few weeks should be ok, but months may be pushing it, as the batteries are being charged and charged and charged without any usage save for leakage. In your case, this sounds unavoidable, so you may want

to look into batteries that are built for this kind of duress, or even consider some type of device that switches off the solar panels when the batteries reach full capacity, and then on again when they become low.

JCG5 (/member/JCG5/) 2013-02-02 Reply

On my battery clip I have a toggle switch. When I have the solar panel charging the batteries, do I leave the switch on or off?

AndroidJack (/member/AndroidJack/) ▸ JCG5 (/member/JCG5/) Reply 2013-07-07

Depends on where the switch is located. If it is switching between the panels and the batteries, then leave it closed (on) so that the panels may charge the batteries. If it is after the batteries, then it really doesn't matter, unless there is a device plugged into the USB. In that case, close the switch to charge the device, and open it to prevent the device from charging. Are you using the switch INSTEAD of a diode? If that is the case, keep the switch closed only when you know the panels can harness sunlight.

Fashiondez (/member/Fashiondez/) 2012-10-14 Reply

Is it okay if I want to hook my two 4.5v 80mAs in a series for just two batteries, to make it more powerful?

GeoGyrl (/member/GeoGyrl/) 2012-02-12 Reply

I am doing some research that requires about 300 AA batteries in a village with no electricity. I want to use the eneloop 2000 as it seems like they will last a long time and also recharge a lot of times. I decided to make solar chargers because $30 each for 30 chargers ON TOP of the battery costs is tough. I'll be right near the equator so sun isn't an issue. Been reading what I can, but what would you EXPERTS recommend to charge 4 AA batteries in about 8 hours? I'm guessing over 6V panel but what ma? I'm thinking of training women to make these little chargers for batteries and cellphones so trying to figure out how to solder without electricity. MAYBE can use butane if I can find a can in the city to recharge the cartridge. I leave in less than three weeks so any help would be appreciated.

hendrosutono (/member/hendrosutono/) ▸ GeoGyrl (/member/GeoGyrl/) Reply 2012-07-26

For soldering u can use any kine of metal with sharp tip...
Heated with any kind of heat source, fire from wood chips would work, nor biogas, kerosene stove, alcohol burner and many more....

Dbaby66 (/member/Dbaby66/) ▸ GeoGyrl (/member/GeoGyrl/) 2012-03-29 Reply

You can find solder guns that use gas to burn. I have one. They are portable and use lighter fluid. You can find them on ebay pretty cheap.

Billybob101 (/member/Billybob101/) ▸ Dbaby66 (/member/Dbaby66/) Reply 2012-04-15

You can get some that you actually put a lighter in. Thats a lot easier than trying to find lighter fluid

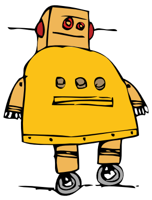
Dbaby66 (/member/Dbaby66/) ▸ Billybob101 (/member/Billybob101/)

Reply

2012-04-15

I will be finding on of those because that is way easier. Thanks.

More Comments



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Diodes

CONTRIBUTORS: *JIMB0*

FAVORITE 32

Introduction

Once you graduate from the simple, passive components that are resistors, capacitors, and inductors, it's time to step on up to the wonderful world of semiconductors. One of the most widely used semiconductor components is the diode.

In this tutorial we'll cover:

- What is a diode!?
- Theory of diode operation
- Important diode properties
- Different types of diodes
- What diodes look like
- Typical diode applications

Suggested Reading

Some of the concepts in this tutorial build on previous electronics knowledge. Before jumping into this tutorial consider reading (at least skimming) these first:

What is a Circuit?
Every electrical project starts with a circuit. Don't know what a circuit is? We're here to help.

Voltage, Current, Resistance, and Ohm's Law
Learn about Ohm's Law, one of the most fundamental equations in all electrical engineering.

What is Electricity?
We can see electricity in action on our computers, lighting our houses, as lightning strikes in thunderstorms, but what is it? This is not an easy question, but this tutorial will shed some light on it!

Series and Parallel Circuits
An introduction into series and parallel circuits.

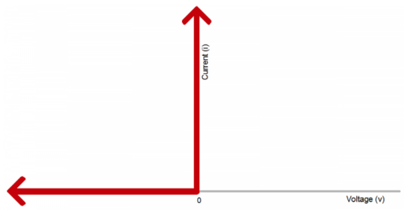
How to Use a Multimeter
Learn the basics of using a multimeter to measure continuity, voltage, resistance and current.

Ideal Diodes

The key function of an **ideal** diode is to control the *direction* of current-flow. Current passing through a diode can only go in one direction, called the forward direction. Current trying to flow the reverse direction is blocked. They're like the one-way valve of electronics.

If the voltage across a diode is negative, no current can flow*, and the ideal diode looks like an open circuit. In such a situation, the diode is said to be *off* or **reverse biased**.

As long as the voltage across the diode isn't negative, it'll "turn on" and conduct current. Ideally* a diode would act like a short circuit (0V across it) if it was conducting current. When a diode is conducting current it's **forward biased** (electronics jargon for "on").



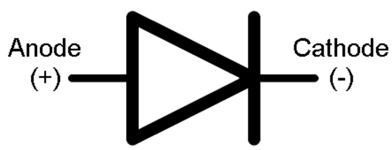
The current-voltage relationship of an ideal diode. Any negative voltage produces zero current – an open circuit. As long as the voltage is non-negative the diode looks like a short circuit.

Ideal Diode Characteristics		
Operation Mode	On (Forward biased)	Off (Reverse biased)
Current Through	I>0	I=0
Voltage Across	V=0	V<0
Diode looks like	Short circuit	Open circuit

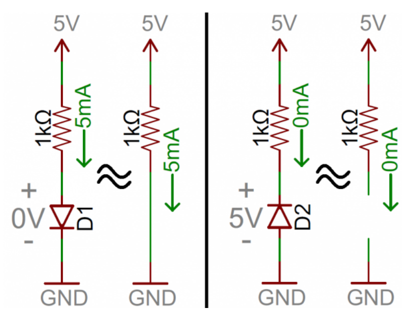
Circuit Symbol

Every diode has **two terminals** – connections on each end of the component – and those terminals are **polarized**, meaning the two terminals are distinctly different. It's important not to mix the connections on a diode up. The positive end of a diode is called the **anode**, and the negative end is called the **cathode**. Current can flow from the anode end to the cathode, but not the other direction. If you forget which way current flows through a diode, try to remember the mnemonic *ACID*: "anode current in diode" (also *anode cathode is diode*).

The **circuit symbol** of a standard diode is a triangle butting up against a line. As we'll cover in the later in this tutorial, there are a variety of diode types, but usually their circuit symbol will look something like this:



The terminal entering the flat edge of the triangle represents the anode. Current flows in the direction that the triangle/arrow is pointing, but it can't go the other way.



Above are a couple simple diode circuit examples. On the left, diode D1 is forward biased and allowing current to flow through the circuit. In essence it looks like a short circuit. On the right, diode D2 is reverse biased. Current cannot flow through the circuit, and it essentially looks like an open circuit.

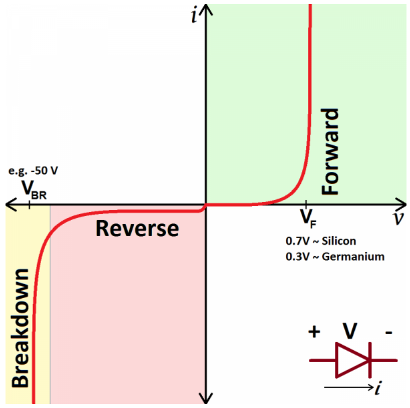
*Caveat! Asterisk! Not-entirely-true… Unfortunately, there's no such thing as an *ideal* diode. But don't worry! Diodes really are real, they've just got a few characteristics which make them operate as a little less than our ideal model…

Real Diode Characteristics

Ideally, diodes will block any and all current flowing the reverse direction, or just act like a short-circuit if current flow is forward. Unfortunately, actual diode behavior isn't quite ideal. Diodes do consume some amount of power when conducting forward current, and they won't block out all reverse current. Real-world diodes are a bit more complicated, and they all have unique characteristics which define how they actually operate.

Current-Voltage Relationship

The most important diode characteristic is its current-voltage (*i-v*) relationship. This defines what the current running through a component is, given what voltage is measured across it. Resistors, for example, have a simple, linear *i-v* relationship…Ohm's Law. The *i-v* curve of a diode, though, is entirely *non*-linear. It looks something like this:



The current-voltage relationship of a diode. In order to exaggerate a few important points on the plot, the scales in both the positive and negative halves are not equal.

Depending on the voltage applied across it, a diode will operate in one of three regions:

1. **Forward bias**: When the voltage across the diode is positive the diode is “on” and current can run through. The voltage should be greater than the forward voltage (V_F) in order for the current to be anything significant.
2. **Reverse bias**: This is the “off” mode of the diode, where the voltage is less than V_F but greater than $-V_{BR}$. In this mode current flow is (mostly) blocked, and the diode is off. A *very* small amount of current (on the order of nA) – called reverse saturation current – is able to flow in reverse through the diode.
3. **Breakdown**: When the voltage applied across the diode is very large and negative, lots of current will be able to flow in the reverse direction, from cathode to anode.

Forward Voltage

In order to “turn on” and conduct current in the forward direction, a diode requires a certain amount of positive voltage to be applied across it. The typical voltage required to turn the diode on is called the *forward voltage* (V_F). It might also be called either the *cut-in voltage* or *on-voltage*.

As we know from the *i-v* curve, the current through and voltage across a diode are interdependent. More current means more voltage, less voltage means less current. Once the voltage gets to about the forward voltage rating, though, large increases in current should still only mean a very small increase in voltage. If a diode is fully conducting, it can usually be assumed that the voltage across it is the forward voltage rating.

A multimeter with a diode setting can be used to measure (the minimum of) a diode’s forward voltage drop.

A specific diode’s V_F depends on what semiconductor material it’s made out of. Typically, a silicon diode will have a V_F around **0.6-1V**. A germanium-based diode might be lower, around 0.3V. The *type* of diode also has some importance in defining the forward voltage drop; light-emitting diodes can have a much larger V_F, while Schottky diodes are designed specifically to have a much lower-than-usual forward voltage.

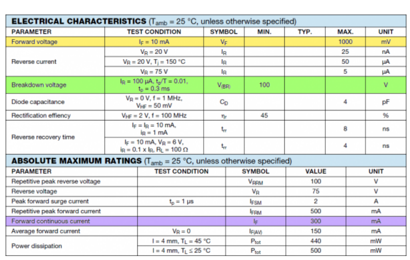
Breakdown Voltage

If a large enough negative voltage is applied to the diode, it will give in and allow current to flow in the reverse direction. This large negative voltage is called the **breakdown voltage**. Some diodes are actually designed to operate in the breakdown region, but for most normal diodes it’s not very healthy for them to be subjected to large negative voltages.

For normal diodes this breakdown voltage is around -50V to -100V, or even more negative.

Diode Datasheets

All of the above characteristics should be detailed in the datasheet for every diode. For example, this datasheet for a 1N4148 diode lists the maximum forward voltage (1V) and the breakdown voltage (100V) (among a lot of other information):



ELECTRICAL CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)

PARAMETER	TEST CONDITION	SYMBOL	MIN.	TYP.	MAX.	UNIT
Forward voltage	I_F = 10 mA	V_F			1000	mV
Reverse current	V_R = 20 V	I_R			25	nA
	V_R = 20 V, T_j = 150 °C	I_R			50	µA
	V_R = 75 V	I_R			5	µA
Breakdown voltage	I_R = 100 µA, t_p/T = 0.01, t_p = 0.3 ms	$V_{(BR)}$	100			V
Diode capacitance	V_R = 0 V, f = 1 MHz, V_{HF} = 50 mV	C_D			4	pF
Rectification effiency	V_{HF} = 2 V, f = 100 MHz	η_r	45			%
Reverse recovery time	$I_F = I_R$ = 10 mA, i_R = 1 mA	t_{rr}			8	ns
	I_F = 10 mA, V_R = 6 V, $i_R = 0.1 \times I_R$, R_L = 100 Ω	t_{rr}			4	ns

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)

PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
Repetitive peak reverse voltage		V_{RRM}	100	V
Reverse voltage		V_R	75	V
Peak forward surge current	t_p = 1 µs	I_{FSM}	2	A
Repetitive peak forward current		I_{FRM}	500	mA
Forward continuous current		I_F	300	mA
Average forward current	V_R = 0	$I_{F(AV)}$	150	mA
Power dissipation	l = 4 mm, T_L = 45 °C	P_{tot}	440	mW
	l = 4 mm, T_L ≤ 25 °C	P_{tot}	500	mW

A datasheet might even present you with a very familiar looking current-voltage graph, to further detail how the diode behaves. This graph from the diode’s datasheet enlarges the curvy, forward-region part of the *i-v* curve. Notice how more current requires more voltage:

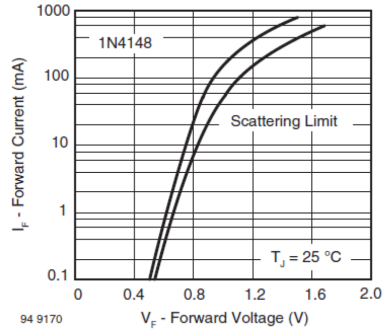


Fig. 2 - Forward Current vs. Forward Voltage

That chart points out another important diode characteristic – the maximum forward current. Just like any component, diodes can only dissipate so much power before they blow. All diodes should list maximum current, reverse voltage, and power dissipation. If a diode is subject to more voltage or current than it can handle, expect it to heat up (or worse; melt, smoke,…).

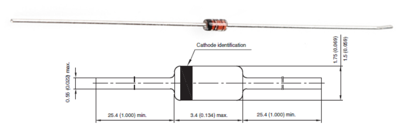
Some diodes are well-suited to high currents – 1A or more – others like the 1N4148 small-signal diode shown above may only be suited for around 200mA.

That 1N4148 is just a tiny sampling of all the different kinds of diodes there are out there. Next we'll explore what an amazing variety of diodes there are and what purpose each type serves.

Types of Diodes

Normal Diodes

Standard **signal diodes** are among the most basic, average, no-frills members of the diode family. They usually have a medium-high forward voltage drop and a low maximum current rating. A common example of a signal diode is the 1N4148. Very general purpose, it's got a typical forward voltage drop of 0.72V and a 300mA maximum forward current rating.

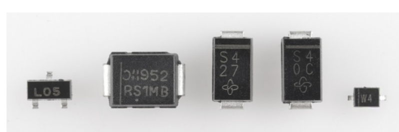


A small-signal diode, the 1N4148. Notice the black circle around the diode, that marks which of the terminals is the cathode.

A **rectifier or power diode** is a standard diode with a much higher maximum current rating. This higher current rating usually comes at the cost of a larger forward voltage. The 1N4001, for example, has a current rating of 1A and a forward voltage of 1.1V.

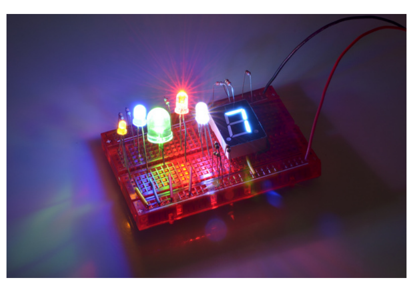
A 1N4001 PTH diode. This time a gray band indicates which pin is the cathode.

And, of course, most diode types come in surface-mount varieties as well. You'll notice that every diode has some way (no matter how tiny or hard to see) to indicate which of the two pins is the cathode.



Light-Emitting Diodes (LEDs!)

The flashiest member of the diode family must be the light-emitting diode (LED). These diodes quite literally light up when a positive voltage is applied.

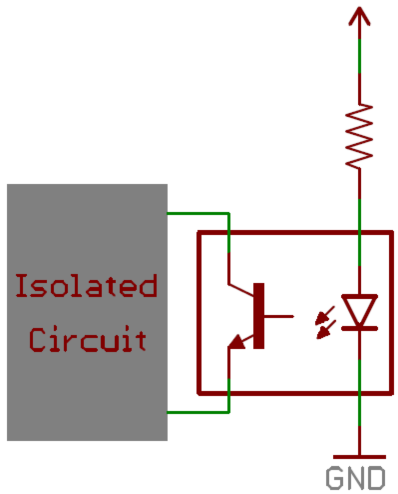


A handful of through-hole LEDs. From left to right: a yellow 3mm, blue 5mm, green 10mm, super-bright red 5mm, an RGB 5mm and a blue 7-segment LED.

Like normal diodes, LEDs only allow current through one direction. They also have a forward voltage rating, which is the voltage required for them to light up. The V_F rating of an LED is usually larger than that of a normal diode (1.2~3V), and it depends on the color the LED emits. For example, the rated forward voltage of a Super Bright Blue LED is around 3.3V, while that of the equal size Super Bright Red LED is only 2.2V.

You'll obviously most-often find LEDs in lighting applications. They're blinky and fun! But more than that, their high-efficiency has lead to widespread use in street lights, displays, backlighting, and much more. Other LEDs emit a light that is not visible to the human eye, like infrared LEDs, which are the backbone of most remote controls. Another common use of LEDs is in optically isolating a dangerous high-voltage system from a lower-voltage circuit. Opto-isolators pair an infrared LED with a photosensor,

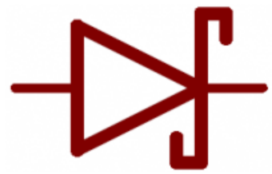
which allows current to flow when it detects light from the LED. Below is an example circuit of an opto-isolator. Note how the schematic symbol for the diode varies from the normal diode. LED symbols add a couple arrows extending out from the symbol.



Schottky Diodes

Another very common diode is the Schottky diode. The semiconductor composition of a Schottky diode is slightly different from a normal diode, and this results in a much **smaller forward voltage drop**, which is usually between 0.15V and 0.45V. They'll still have a very large breakdown voltage though.

Schottky diodes are especially useful in limiting losses, when every last bit of voltage *must* be spared. They're unique enough to get a circuit symbol of their own, with a couple bends on the end of the cathode-line.

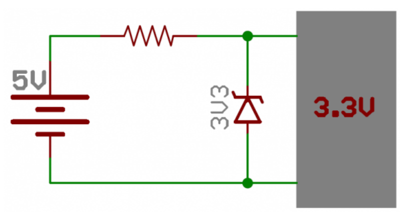


Zener Diodes

Zener diodes are the weird outcast of the diode family. They're usually used to intentionally **conduct reverse current**. Zener's are designed to have a very precise breakdown voltage, called the **zener breakdown** or **zener voltage**. When enough current runs in reverse through the zener, the voltage drop across it will hold steady at the breakdown voltage.

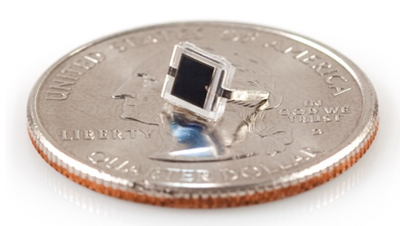
Taking advantage of their breakdown property, Zener diodes are often used to create a known reference voltage at exactly their Zener voltage. They can be used as a voltage regulator for small loads, but they're not really made to regulate voltage to circuits that will pull significant amounts of current.

Zeners are special enough to get their own circuit symbol, with wavy ends on the cathode-line. The symbol might even define what, exactly, the diode's zener voltage is. Here's a 3.3V zener diode acting to create a solid 3.3V voltage reference:



Photodiodes

Photodiodes are specially constructed diodes, which capture energy from photons of light (see Physics, quantum) to generate electrical current. Kind of operating as an anti-LED.



A BPW34 photodiode (not the quarter, the little thing on top of that). Get it under the sun and it can generate about few µW's of power!.

Solar cells are the main benefactor of photodiode technology. But these diodes can also be used to detect light, or even communicate optically.

Diode Applications

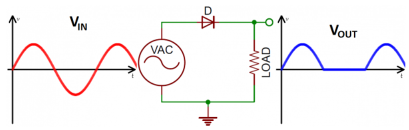
For such a simple component, diodes have a huge range of uses. You'll find a diode of some type in just about every circuit. They could be featured in anything from a small-signal digital logic to a high voltage power conversion circuit. Let's explore some of these applications.

Rectifiers

A rectifier is a circuit that converts alternating current (AC) to direct current (DC). This conversion is critical for all sorts of household electronics. AC signals come out of your house's wall outlets, but DC is what powers most computers and other microelectronics.

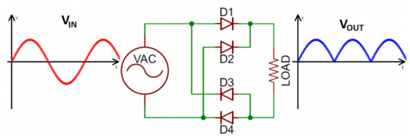
Current in AC circuits literally *alternates* – quickly switches between running in the positive and negative directions – but current in a DC signal only runs in one direction. So to convert from AC to DC you just need to make sure current can't run in the negative direction. Sounds like a job for DIODES!

A **half-wave rectifier** can be made out of just a single diode. If an AC signal, like a sine wave for example, is sent through a diode any negative component to the signal is clipped out.



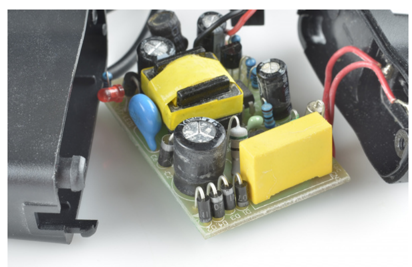
Input (red/left) and output (blue/right) voltage waveforms, after passing through the half-wave rectifier circuit (middle).

A **full-wave bridge rectifier** uses four diodes to convert those negative humps in the AC signal into positive humps.



The bridge rectifier circuit (middle), and the output wave form it creates (blue/right).

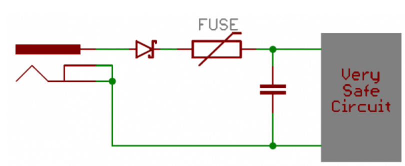
These circuits are a critical component in AC-to-DC power supplies, which turn the wall outlet's 120/240VAC signal into 3.3V, 5V, 12V, etc. DC signals. If you tore apart a wall-wart, you'd most likely see a handful of diodes in there, rectifying it up.



Can you spot the four diodes making a bridge rectifier in this wall-wart?

Reverse Current Protection

Ever stick a battery in the wrong way? Or switch up the red and black power wires? If so, a diode might be to thank for your circuit still being alive. A diode placed in series with the positive side of the power supply is called a reverse protection diode. It ensures that current can only flow in the positive direction, and the power supply only applies a positive voltage to your circuit.



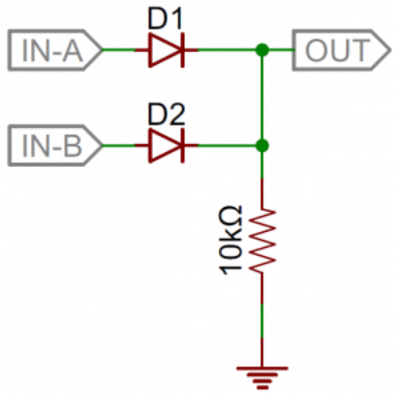
This diode application is useful when a power supply connector isn't polarized, making it easy to mess up and accidentally connect the negative supply to the positive of the input circuit.

The drawback of a reverse protection diode is that it'll induce some voltage loss because of the forward voltage drop. This makes **Schottky diodes** an excellent choice for reverse protection diodes.

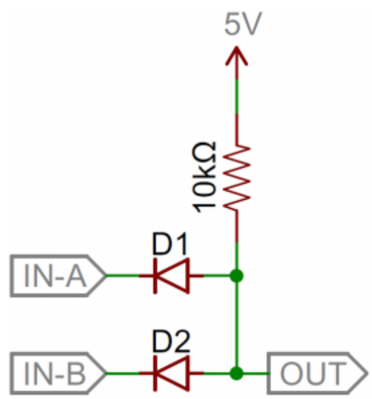
Logic Gates

Forget transistors! Simple digital logic gates, like the AND or the OR, can be built out of diodes.

For example, a diode two-input OR gate can be constructed out of two diodes with shared cathode nodes. The output of the logic circuit is also located at that node. Whenever either input (or both) is a logic 1 (high/5V) the output becomes a logic 1 as well. When both inputs are a logic 0 (low/0V), the output is pulled low through the resistor.



An AND gate is constructed in a similar manner. The *anodes* of both diodes are connected together, which is where the output of the circuit is located. Both inputs must be logic 1 forcing current to run towards the output pin and pull it high also. If either of the inputs are low, current from the 5V supply runs through the diode.

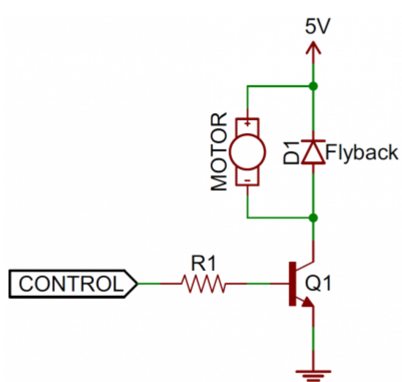


For both logic gates, more inputs can be added by adding just a single diode.

Flyback Diodes and Voltage Spike Suppression

Diodes are very often used to limit potential damage from unexpected large spikes in voltage. Transient-voltage-suppression (TVS) diodes are specialty diodes, kind of like zener diodes – lowish breakdown voltages (often around 20V) – but with very large power ratings (often in the range of kilowatts). They're designed to shunt currents and absorb energy when voltages exceed their breakdown voltage.

Flyback diodes do a similar job of suppressing voltage spikes, specifically those induced by an inductive component, like a motor. When current through an inductor suddenly changes, a voltage spike is created, possibly a very large, negative spike. A flyback diode placed across the inductive load, will give that negative voltage signal a safe path to discharge, actually looping over-and-over through the inductor and diode until it eventually dies out.



That's just a handful of applications for this amazing little semiconductor component.

Purchasing Diodes

Now that your *current* is flowing in the right direction, it's time to put your new knowledge to good use. Whether you're looking for a starting point or just stocking up, we've got an Inventor's Kit as well individual diodes to choose from.

Our recommendations:

Diode Small Signal - 1N4148
COM-08588
$0.15

Diode Rectifier - 1A 50V
COM-08589
$0.15

Schottky Diode
COM-10926
$0.15
1

SparkFun Inventor's Kit - V3.2
KIT-12060
76 **Retired**

Resources and Going Further

Now that you've gotten a handle on diodes, maybe you'd like to further explore more semiconductors:

- Transistors
- LEDs
- Or learn about integrated circuits, like:
  - 555 Timers
  - Operational Amplifiers
  - Shift Registers

Or discover some of the other common electronic components:

- Resistors
- Capacitors
- Inductors
- Voltage Regulators

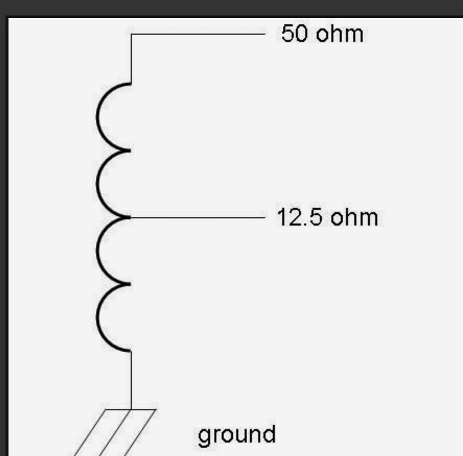
du1vss home brews

All about ham radio. Although some of my projects involved transmitters, rf amplifiers and antennas that operates outside the ham band, these things were solely for educational purpose only and experimentation.

Sunday, July 13, 2014

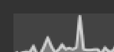
4:1 Unbalance to Unbalance Coaxial Transformer

This is my first time to implement the 4:1 unbalance to unbalance coaxial transformer to match the input and output impedance of an rf power transistor. My prototype rf amplifier originally had a lumped LC network in both input and output sections and only have +/- 3MHz of bandwidth but after the addition of 4:1 coaxial transformer, the bandwidth has now increased to +/- 6MHz from the center tuning frequency of the amplifier.
The coaxial transformer is about 1/16th wavelength long from the highest frequency in which the amplifier will work and should have 25 ohm of characteristic impedance. In my prototype amp it uses a pair of RG-178 cable paralleled to arrive at the 25 ohm requirement.



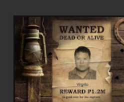
This is the simplified diagram when looking at the transformer however, the characteristic impedance of the coaxial cable also plays an important role in the impedance ratio. For a 50 ohm to 12.5 ohm transformation, it calls for a 25 ohm cable but since I don't have this kind, I simply paralleled two RG178, a 50 ohm cable.

Total Pageviews



45,085

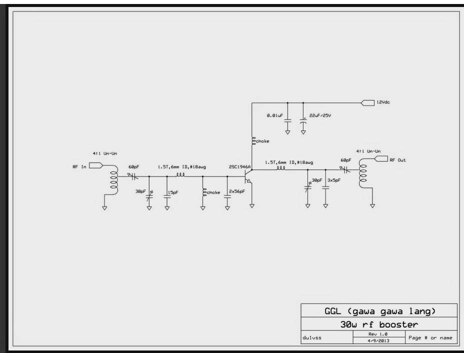
About Me



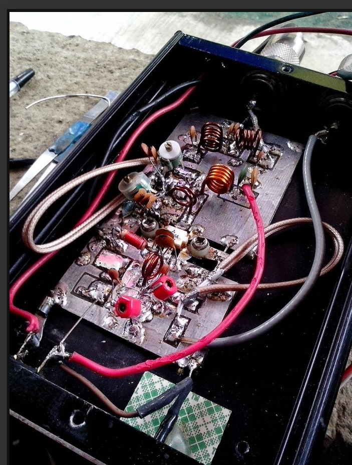
hevirred

Ham since 2000.

View my complete profile



The schematic diagram of my prototype amp tells that aside from the 4:1 coaxial transformer, LC network was still employed to further matched the impedance of the base and collector of the power rf transistor. The only limiting factor that prevents the amplifier for a broadband operation is the LC network!



My prototype amp after the inclusion of the 4:1 coaxial transformer. I might replace the old PCB to facilitate the addition of the two coaxial transformer. ---73 de du1vss

Posted by hevirred at 4:40 PM

G+

3 comments:

ce8d632a-647c-11e3-94d3-000bcdcb2996 July 17, 2014 at 12:13 PM

This comment has been removed by a blog administrator.

Reply

Obaidullah Khan Kakar June 28, 2016 at 12:16 AM

nice one dear

Reply

hevirred June 28, 2016 at 6:29 PM

tnx.

Reply

Enter your comment...

Comment as: Karl Smirni (Gc Sign out

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TRF RADIOS
Part 5
More of Augustin's Radio Projects

Home | Contact | Site Map | Links | Radio Stations & Memorabilia | Amateur Radio

Back to TRF RADIOS Part 1
Back to Home Page
Radio, Stations & Memorabilia
Crystal Sets
Resistor Codes & Capacitor Conversion Tables
Riding On A Wave

TO T.R.F. RADIOS - PART 1 TO T.R.F. RADIOS - PART 2 TO T.R.F. RADIOS - PART 3
TO T.R.F. RADIOS - PART 4 TO T.R.F. RADIOS PART 6 TO T.R.F. RADIOS PART 7
AMATEUR RADIO BRMB Radio Birmingham
LINKS to Other Great Websites

AUGUSTIN'S RADIOS - Continued:

Augustin for Romania had kindly sent us some more photographs of his radio projects. He writes:

"I built it in a larger matchbox, 79x55x34 mm. I'm very satisfied with this radio. I receive loud and clear 2 stations here during the day, but in the night I can pick up more. The schematic it's not mine. Here it is:

http://www.mikroelektronika.co.yu/english/product/books/rrbook/chapter3/chapter3g.htm

When I built it I found, I guess so, the ideal values for the components. For example, it is very important to use the 100nF capacitor from pin 6 to negative. Without this capacitor the amplifier oscillates. I have a small volume pot but I don't use it. I tuned the volume with the screwdriver at the highest value. If I turn more, the radio oscillates. So, the value of the pot is 50K instead of the 47K pot, I put a 27K resistor. It works perfectly like this. I also didn't use R4. I put just the 47nF capacitor. I have a slide switch to turn the radio on or off.

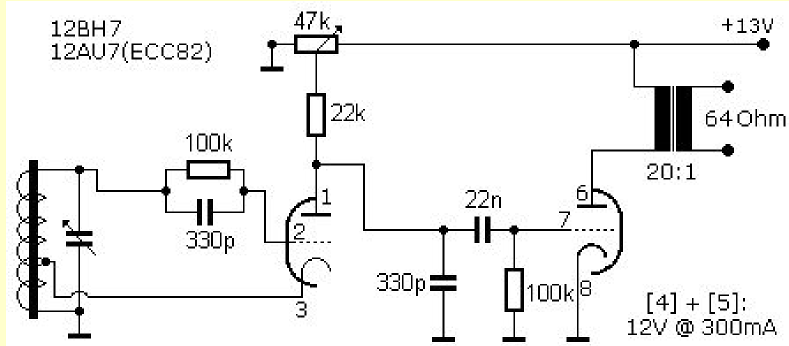
Maybe someone wants to ask me something. I'll be glad to reply, here my email address:

augustin87r@yahoo.com

Best wishes,
Augustin

Below: Augustin informs us that a kind gentleman from the USA sent him some matchboxes, so the radio is now housed in a "Grants Cabin" matchbox.

AUGUSTIN STANCU'S ONE VALVE RADIO PROJECT - 2009



Here is my one tube radio project. Somebody gave me the schematic, he said that he'd copied the schematic from a kit he bought and then improved it. It is very simple and can be built very fast. I improved it even more adding an audio amplifier. After testing the radio I may even make a nice wooden box for it. The radio is working on the Medium Wave AM, but with another coil, it can also receive the Short Wave.

The coil is important as it determines the tuning range. The coil that I used was taken from an old radio. It is about 17cm long and 1 cm thick. The small winding has 7 turns and the larger one has 70 turns.

I powered my radio from a 12V-9Ah motorcyle lead acid battery, but I think a dry 12V - 1,2 A will be enough for a few hours of listening....

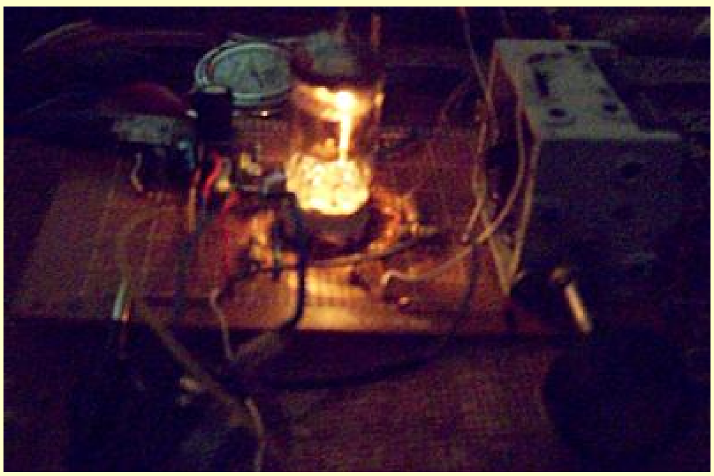


Photo Left: Augustin's One Valve Radio Glowing In The Dark!

I made a solid state AF amplifier stage for the radio. Although I initially wanted to build an amplifier with germanium transistors, the amplifier section that I eventually settled upon consists of the well known LM386 integrated circuit, using a BC109 transistor as the preamplifier for the LM386. The anode load is provided by a 34K resistor instead of the transformer used in the original one valve circuit.

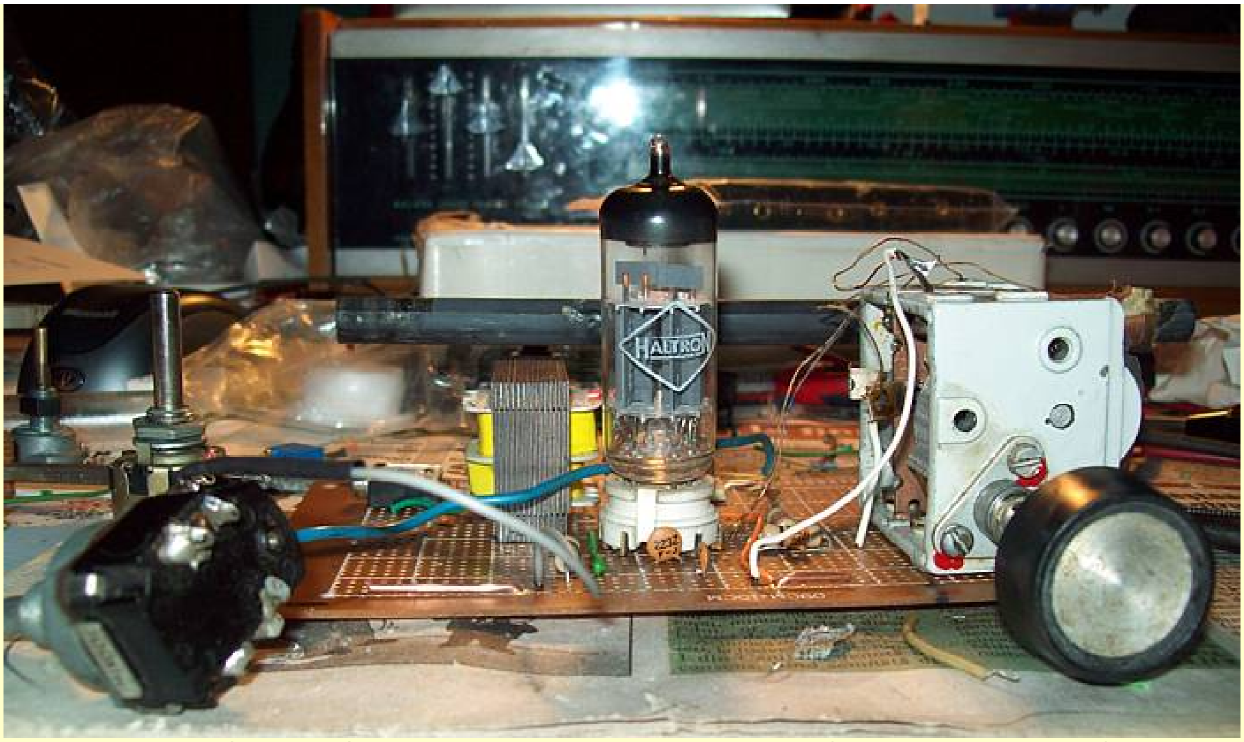
Now I have the perfect hybrid radio: Tube, Transistor and I.C. I even posted a clip on youtube with the sound.

People can build this radio as they may like; either for listening with an earpiece or with a loudspeaker speaker so everyone can hear.

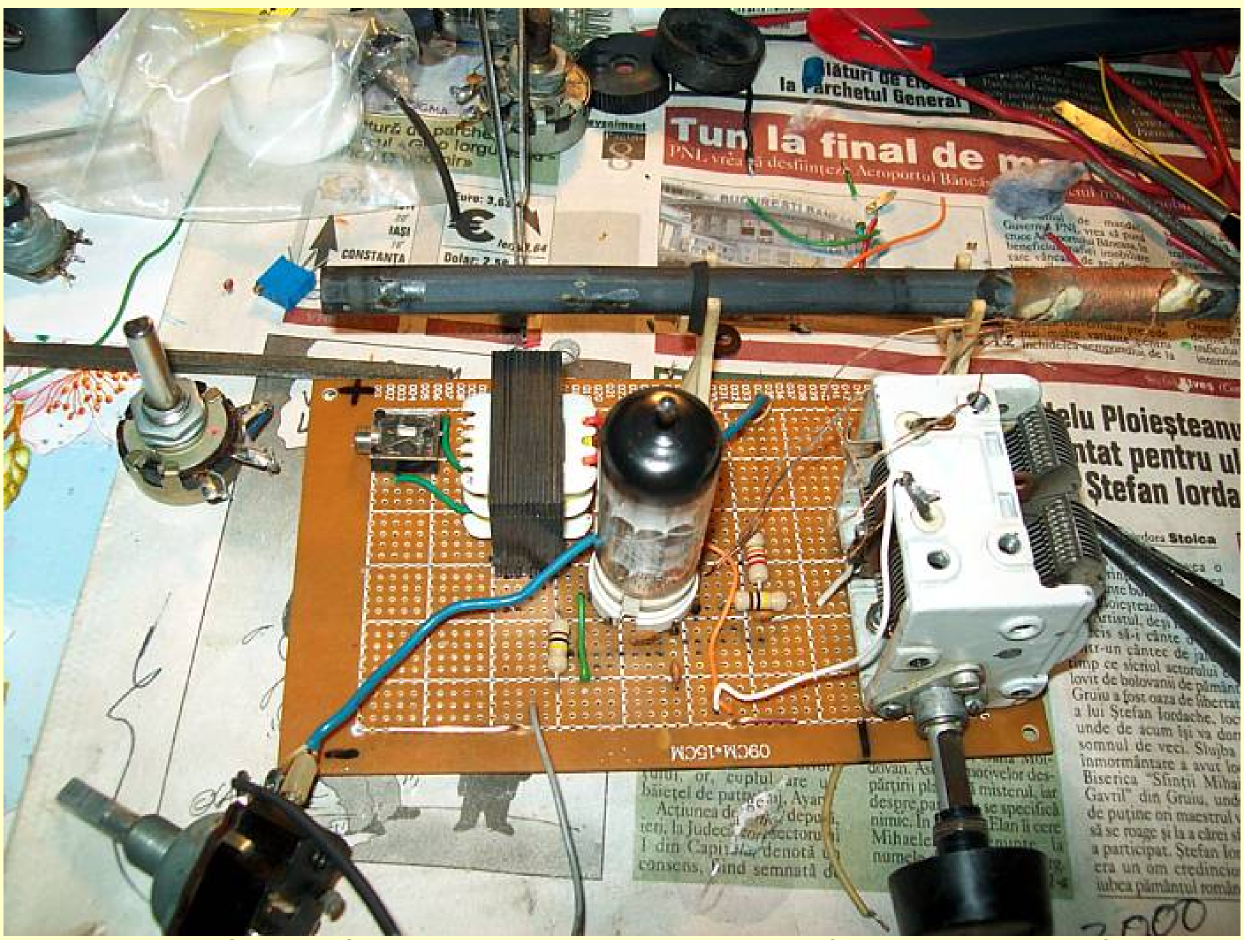
I think people will like to build a radio that 'glows in the dark' especially because it doesn't need a high anodic voltage. People are always fascinated about matchbox radios and tube radios :-)

Best regards, Augustin Stancu. November 2009
augustin87r@yahoo.com

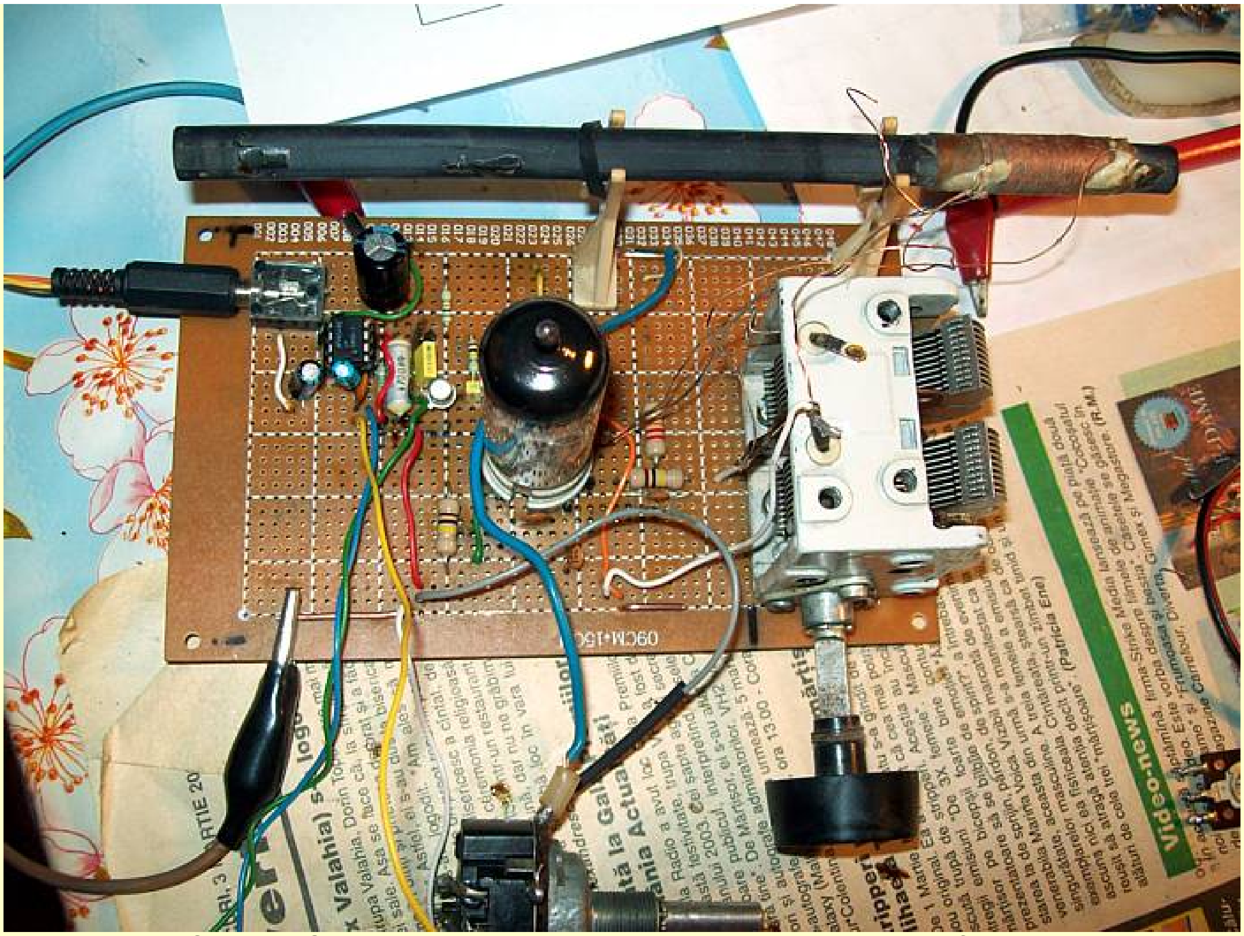
Here are the photographs that should explain everything. They say that a picture is worth a thousand words!



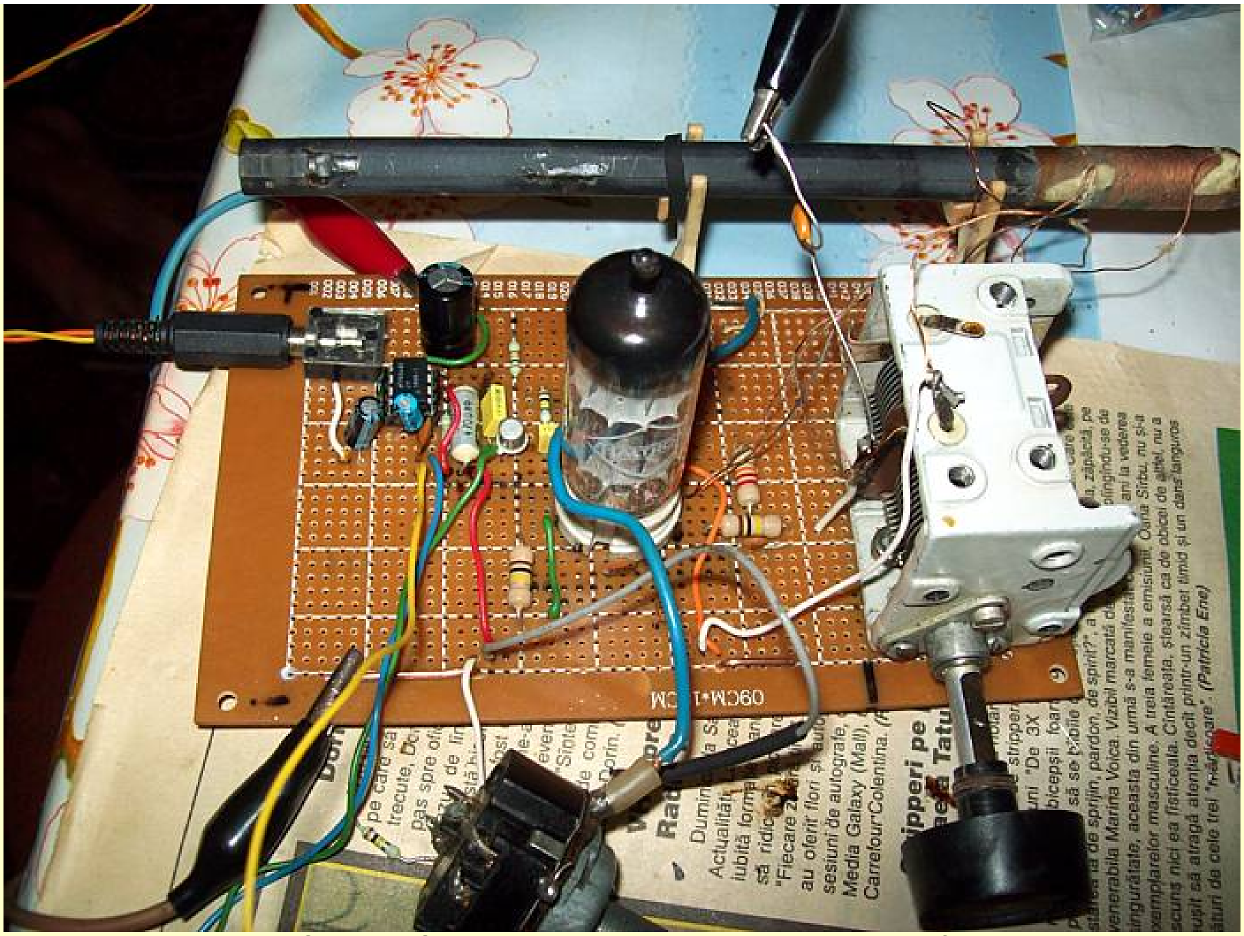
Augustin Stancu's One Valve Radio in its basic one valve form without AF amplifier



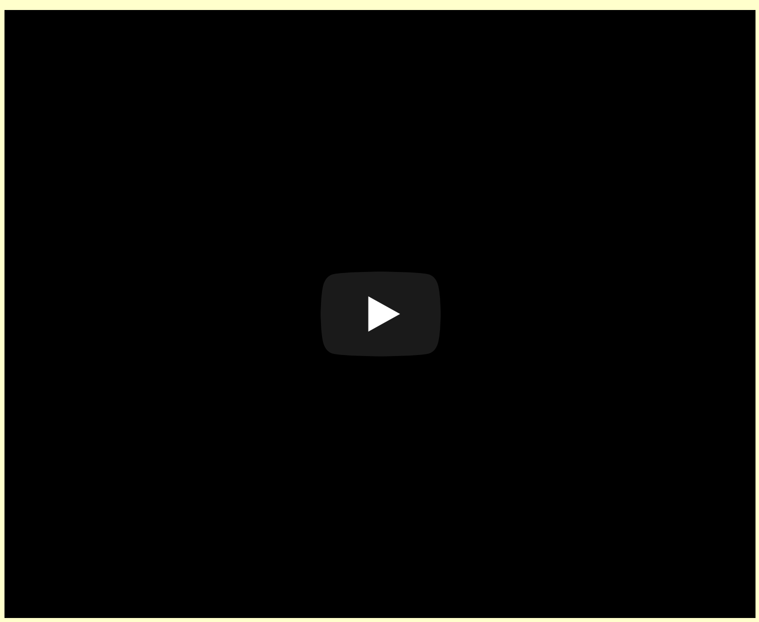
Augustin Stancu's One Valve Radio in its basic one valve form without AF amplifier



Augustin Stancu's One Valve Radio with additional solid state AF amplifier stages added



Augustin Stancu's One Valve Radio with solid state AF amplifier stage.



Above is a video of the working radio. The programme is in Romanian.
At that time I had the LF amplifier built with wires (we call it 'spider') for testing. It looks ugly! The sound is better in reality than that produced on YouTube.

THE HAC MODEL "T" TWIN TRANSISTOR RADIO KIT

The HAC company of East Grinstead, Sussex, produced radio kits for home construction radio enthusiasts and short wave listeners. The three transistor circuit is described above, but Jake Haskell very kindly sent MDS975 photographs of his original HAC Model "T" Twin Transistor short wave radio instruction booklet.

You can download the PDF file of the HAC Model "T" Twin Transistor Radio Kit instruction booklet HERE

You will also need to have a PDF viewer, such as Adobe Reader, installed on your computer - but this is a simple matter. Visit http://www.adobe.com/ to download Adobe Reader.

Link To More Electronic Projects

Visit the EVERYDAY AND PRACTICAL ELECTRONICS Website

No AM radio stations or transmitters in your locality or country?

Has your local medium wave broadcast station closed or been moved to VHF/FM or Digital? Don't worry. You can still build and experiment with crystal sets and TRF radios by also buying or even building a simple low power AM transmitter. So, not only can you use your crystal sets but you can also run your own radio station that can be heard in and around your home - playing the music or programmes that you want to hear!

SSTRAN AMT3000 Superb high fidelity medium wave AM transmitter kits from SSTRAN. Versions available for 10kHz spacing in the Americas (AMT3000 or AMT3000-SM) and 9kHz spacing in Europe and other areas (AMT3000-9 and AMT3000-9SM). Superb audio quality and a great and well designed little kit to build: http://www.sstran.com/pages/products.html

http://www.sstran.com/

Other AM transmitters available:

Spitfire & Metzo Complete, high quality ready built medium wave AM Transmitters from Vintage Components:
http://www.vcomp.co.uk/index.htm Vintage Components offer a choice of the high quality Spitfire and Metzo transmitters:

SPITFIRE AM Medium Wave Transmitter with 100 milliwatt RF output power:

http://www.vcomp.co.uk/spitfire/spitfire.htm

METZO AM Medium Wave Transmitter with built in compressor:

http://www.vcomp.co.uk/metzo/metzo.htm

AM88 LP A basic AM transmitter kit from North County Radio.
http://www.northcountryradio.com/Kitpages/am88.htm

T.R.F. RADIOS PART 1

T.R.F. RADIOS PART 2

T.R.F. RADIOS PART 3

T.R.F. RADIOS PART 4

T.R.F. RADIOS PART 6

T.R.F. RADIOS PART 7

LINKS to Other Great Websites

RESISTOR COLOUR CODES
AND CAPACITOR CONVERSION TABLE

LINKS

More TRF Radio Websites:

Gilbert Davey's Radio Sets - A growing resource for all who either remember building radio sets to his designs or would simply like to find out more: http://www.daveysradios.org.uk

Vintage Radio - TRF Radio Designs: http://www.vintageradio.me.uk/radconnav/transtrf/

Vintage Radio - Home Page: http://www.vintageradio.me.uk/

Vintage Radio - Circuit diagrams for crystal sets, TRF and superhet radios, valve and transistor designs: http://www.vintageradio.me.uk/radconnav/radcon.htm

TRF Designs on Birmingham Alabama Crystal Radio Group: http://www.crystalradio.us/1adradios/1ad-2007-2.htm

Stay Tuned Crystal Radio Resources http://www.crystalradio.net/

Regen Radio Tutorial N1TEV : http://www.electronics-tutorials.com/receivers/regen-radio-receiver.htm

Coil Calculations: http://bellsouthpwp2.net/w/u/wuggy/coils.html

E.P.E. Everyday and Practical Electroncs Magazine: http://www.epemag3.com/

The Radio Board Forums - incl Audion Receiver: http://theradioboard.com

Amateur Radio

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BRMB Radio Birmingham
ILR Birmingham
Independent Local Radio
Birmingham 96.4 FM BRMB
Les Ross - Tony Butler - George Gavin - BRMB Radio Birmingham 96.4 FM - 94.8 FM - 261 metres medium wave

Antennas - Radiowave Propagation - Mobile Systems

V2 618 Laboratory: Theoretical models, computer simulation, optimisation

V2 721 Laboratory: Antenna measurements, anechoic chamber

Staff: Teachers, scientific workers

Dr. Ferenc Lénárt

Dr. Lajos Nagy

Tel: +36 1 463 2791

E-mail: t-nagy@nov.mht.bme.hu

László Szücs

Students:

3 PhD students

10 graduate students

1. **Antenna developments, antenna problems**
   a. **Multiple band antennas**
   Development of dual band indoor base station antennas for the 900 and 1800 MHz bands, omnidirectional and sectorial characteristics
   Design, optimisation, manufacturing of the prototype, measurements
   b. **High gain antennas - Yagi antennas**
   Optimisation, design, measurements
   c. **Log-periodic, helix antennas**
   Design, measurements
   d. **Mutual coupling between antennas**
   Wire grid modells, near field calculations
   e. **Direction finding antenna systems: HF and UHF bands**
2. **Radio links, propagation models**
   a. **Design and analysis of microwave links**
   Digital maps: elevation model,
   b. **Indoor and outdoor mobile radiowave propagation problems**
   Development of propagation models, verification
   Coverage calculation

Projects

Using Digital Elevation Map/ Digital Terrain Map of Hungary

(Resolution of 50x50 meters)

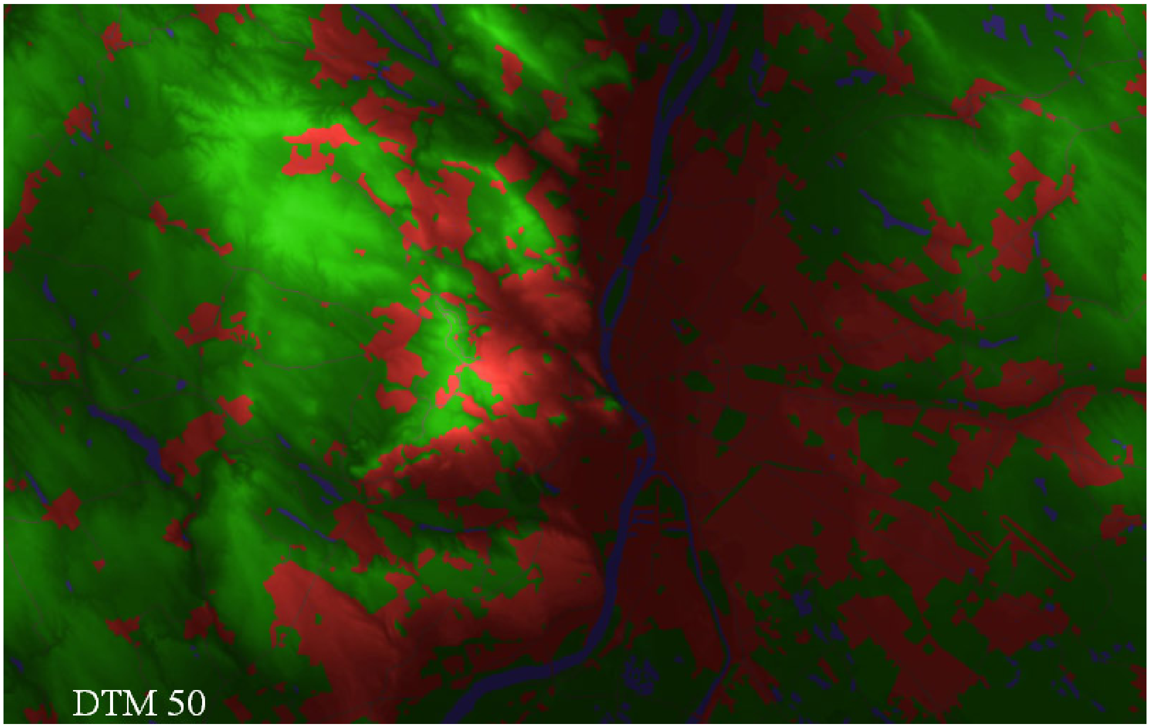


Fig. 1. DTM50 Digital Elevation and Coverage Layers

Wave Propagation Simulations

Microwave links

Fig. 2. Multiple obstacle diffraction

Semi empirical models for mobile macrocells

Fig. 3. Coverage prediction for 450 MHz

Semi empirical models for microcells and picocells

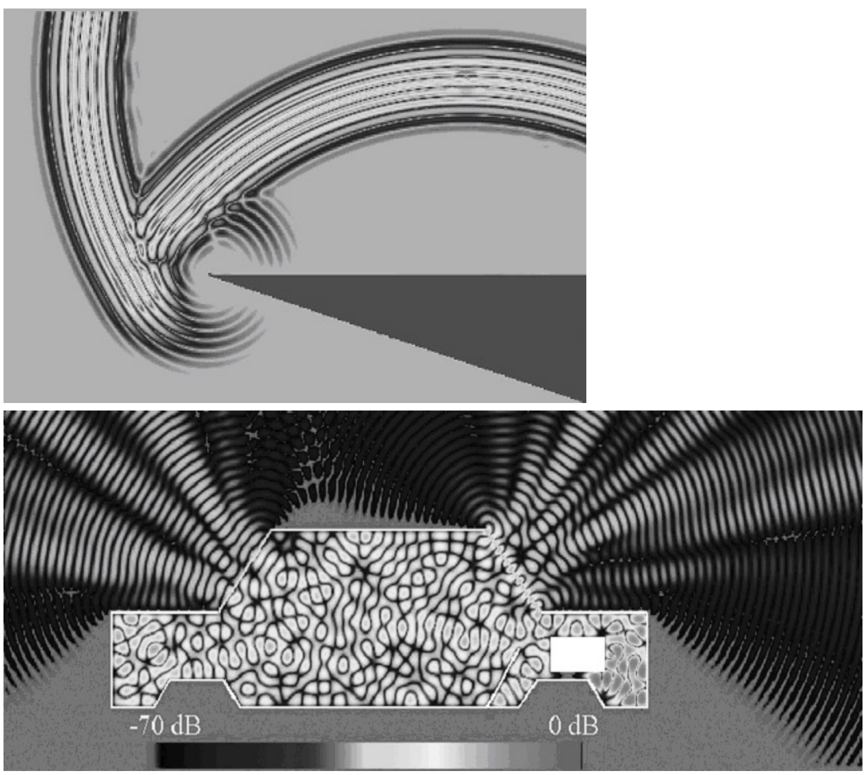
Fig. 4. Stereographic aerial photo

Fig. 5. Vectorial data base

Fig. 6. Prediction and measurement for 900 MHz (Route E1-E2)

Application of ray tracing and FDTD methods for indoor propagation

Fig. 7. Indoor coverage (using 3D ray tracing)



Single lossy dielectric diffraction 2D FDTD simulation (EMC)

Fig. 8. Field strength distribution

Radio Propagation Measurements

Fig. 9. Transmission loss measurement (through wall)

Fig. 10. Indoor floorplan

Fig. 11. Mobile measurement equipment (Spectrum analyser)

Antenna design and measurement

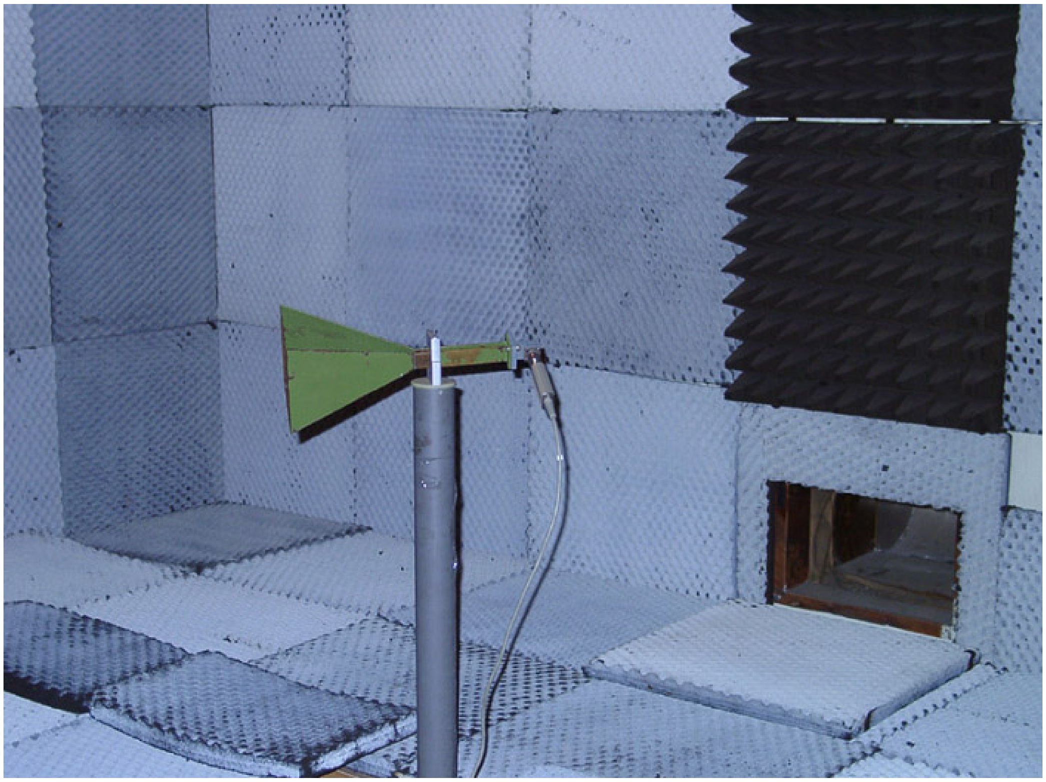


Fig. 12. Anechoic chamber for antenna measurements

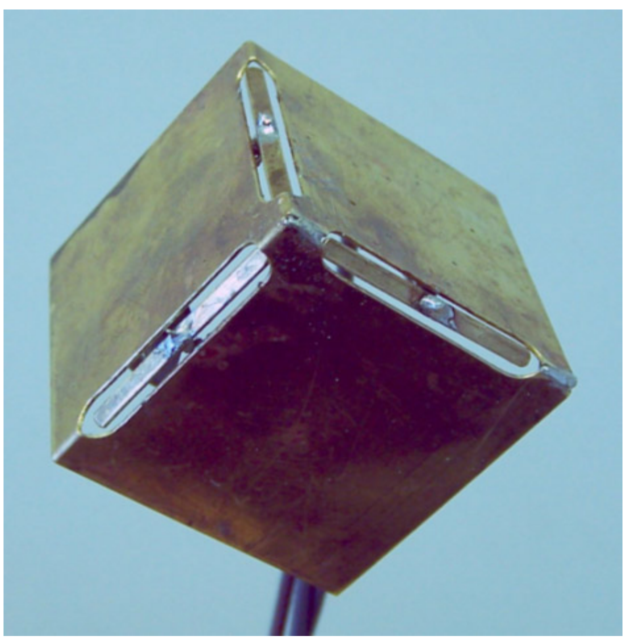


Fig. 13. MIMO antenna (slot dipoles)

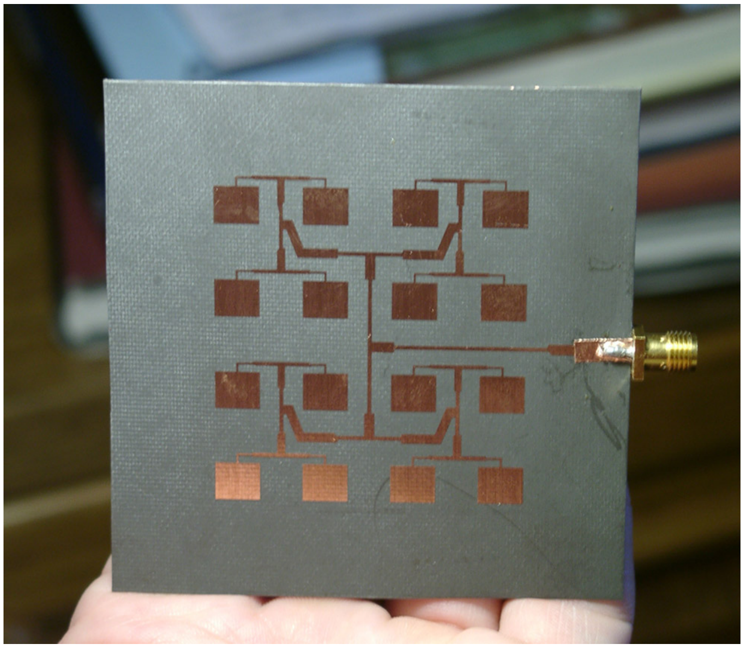


Fig. 14. Microstrip antenna (16 GHz)

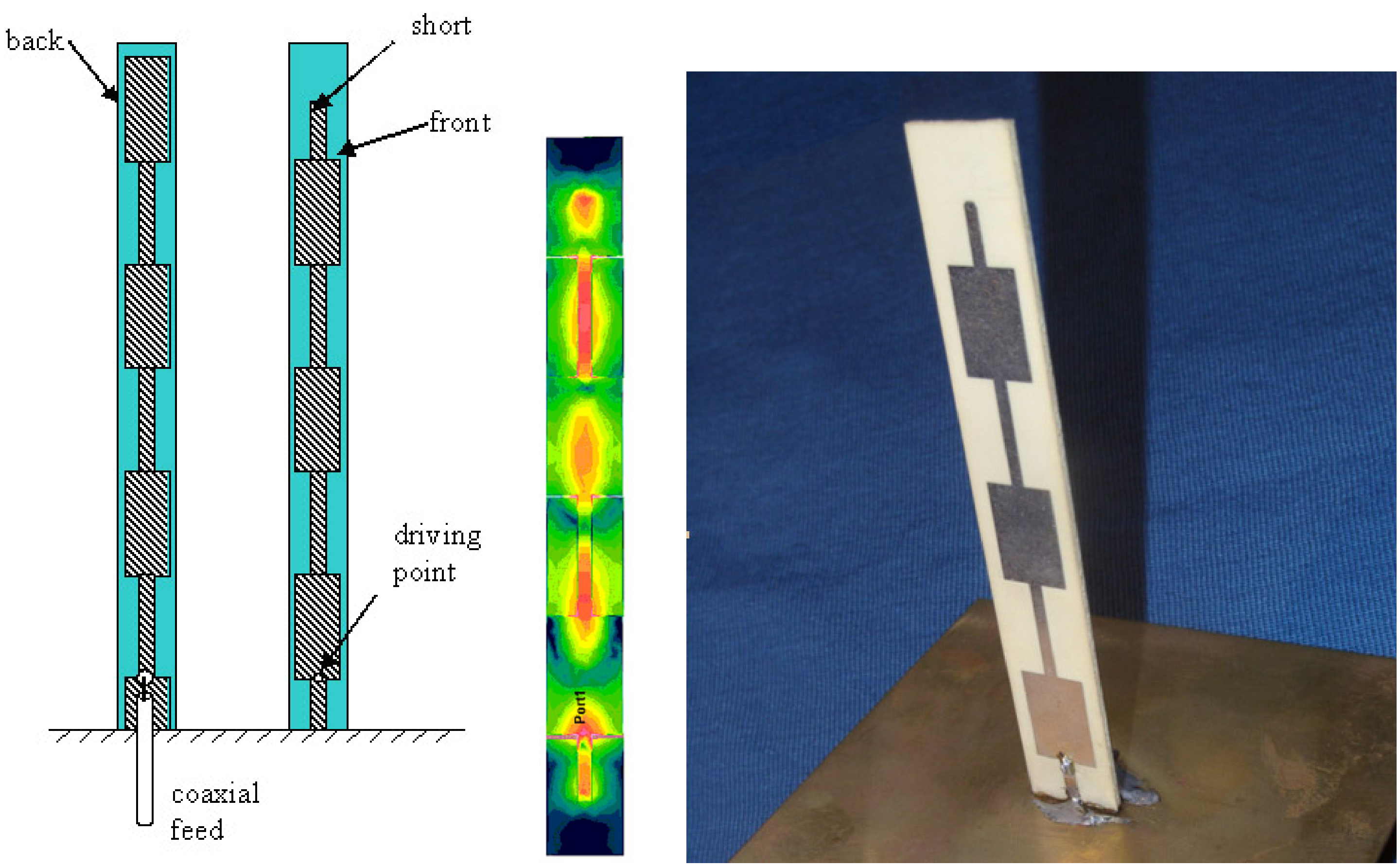


Fig. 15. Planar collinear monopole antenna

Optimisation of wireless networks

Fig. 16. Optimisation of indoor base station locations using Genetic Algorithm

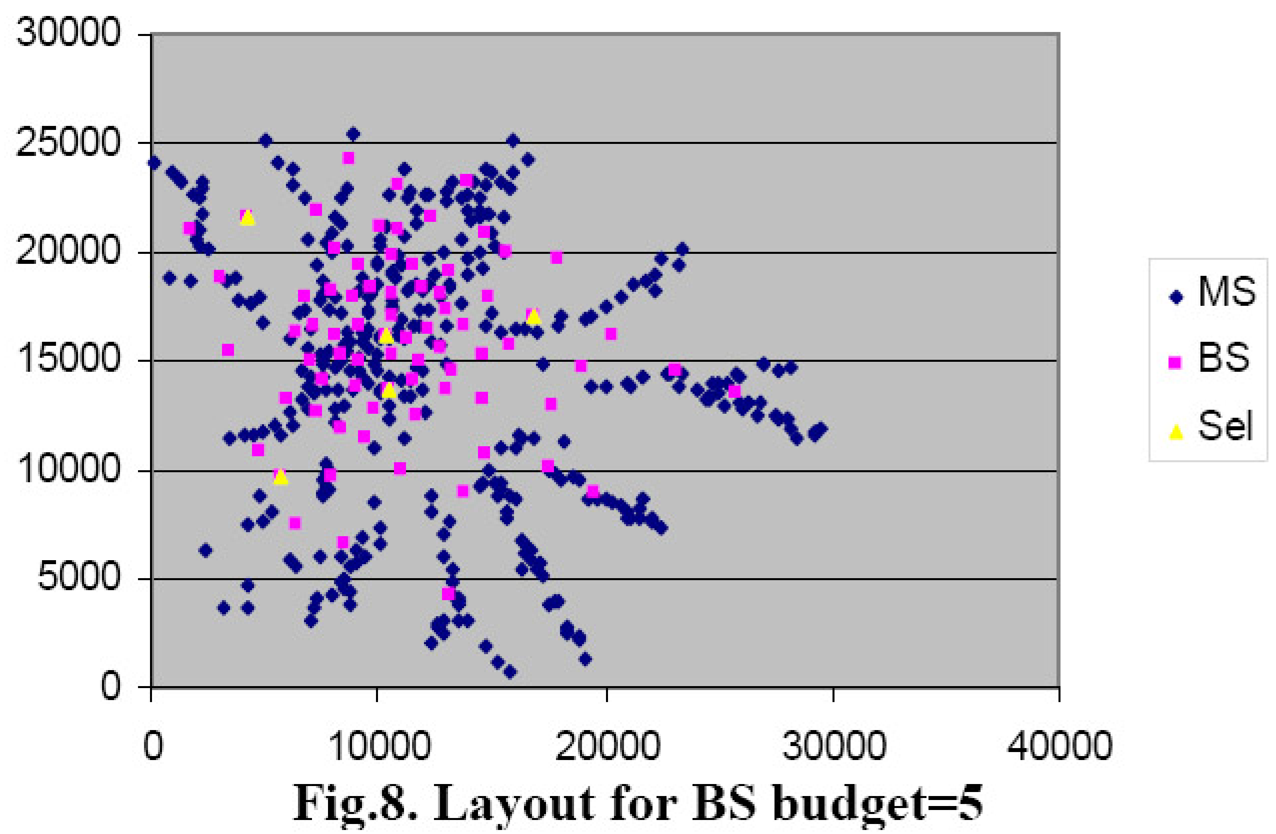


Fig. 17. 3G base station positioning using simulated annealing

antenna

wave propagation

MIMO

UWB

ray tracing

fdtd

Lajos Nagy

Antenna (radio)

From Wikipedia, the free encyclopedia

In radio and electronics, an **antenna** (plural **antennae** or **antennas**), or **aerial**, is an electrical device which converts electric power into radio waves, and vice versa.[1] It is usually used with a radio transmitter or radio receiver. In transmission, a radio transmitter supplies an electric current oscillating at radio frequency (i.e. a high frequency alternating current (AC)) to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals, that is applied to a receiver to be amplified.

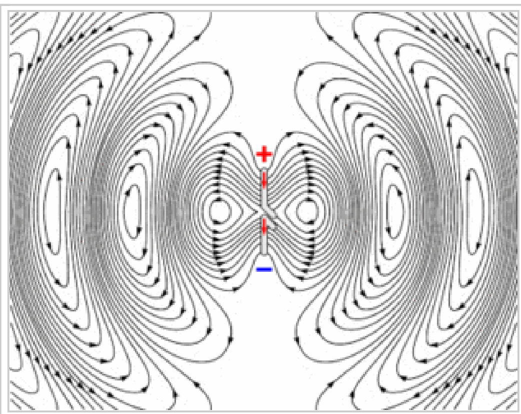
Antennas are essential components of all equipment that uses radio. They are used in systems such as radio broadcasting, broadcast television, two-way radio, communications receivers, radar, cell phones, and satellite communications, as well as other devices such as garage door openers, wireless microphones, Bluetooth-enabled devices, wireless computer networks, baby monitors, and RFID tags on merchandise.

Typically an antenna consists of an arrangement of metallic conductors (elements), electrically connected (often through a transmission line) to the receiver or transmitter. An oscillating current of electrons forced through the antenna by a transmitter will create an oscillating magnetic field around the antenna elements, while the charge of the electrons also creates an oscillating electric field along the elements. These time-varying fields radiate away from the antenna into space as a moving transverse electromagnetic field wave. Conversely, during reception, the oscillating electric and magnetic fields of an incoming radio wave exert force on the electrons in the antenna elements, causing them to move back and forth, creating oscillating currents in the antenna.

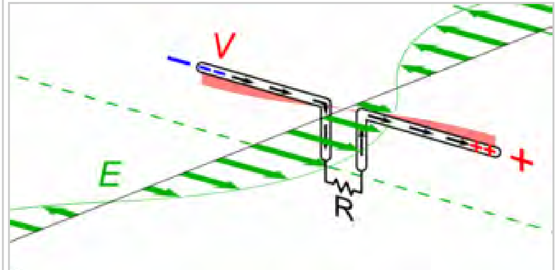
Antennas can be designed to transmit and receive radio waves in all horizontal directions equally (omnidirectional antennas), or preferentially in a particular direction (directional or high gain antennas). In the latter case, an antenna may also include additional elements or surfaces with no electrical connection to the transmitter or receiver, such as parasitic elements, parabolic reflectors or horns, which serve to direct the radio waves into a beam or other desired radiation pattern.

The first antennas were built in 1888 by German physicist Heinrich Hertz in his pioneering experiments to prove the existence of electromagnetic waves predicted by the theory of James Clerk Maxwell. Hertz placed dipole antennas at the focal point of parabolic reflectors for both transmitting and receiving. He published his work in *Annalen der Physik und Chemie* (vol. 36, 1889).

Contents

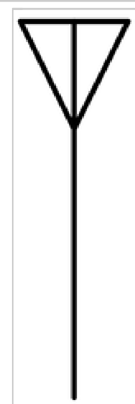


Animation of a half-wave dipole antenna transmitting radio waves, showing the electric field lines. The antenna in the center is two vertical metal rods, with an alternating current applied at its center from a radio transmitter *(not shown)*. The voltage charges the two sides of the antenna alternately positive *(+)* and negative *(−)*. Loops of electric field *(black lines)* leave the antenna and travel away at the speed of light; these are the radio waves.



Animated diagram of a half-wave dipole antenna receiving energy from a radio wave. The antenna consists of two metal rods connected to a receiver *R*. The electric field *(E, green arrows)* of the incoming wave pushes the electrons in the rods back and forth, charging the ends alternately positive *(+)* and negative *(−)*. Since the length of the antenna is one half the wavelength of the wave, the oscillating field induces standing waves of voltage *(V, represented by red band)* and current in the rods. The oscillating currents *(black arrows)* flow down the transmission line and through the receiver (represented by the resistance *R*).

Terminology


Electronic symbol for an antenna

The words *antenna* (plural: *antennas*[2] in US English, although both "antennas" and "antennae" are used in International English[3]) and *aerial* are used interchangeably. Occasionally the term "aerial" is used to mean a wire antenna. However, note the important international technical journal, the *IEEE Transactions on Antennas and Propagation*.[4] In the United Kingdom and other areas where British English is used, the term aerial is sometimes used although 'antenna' has been universal in professional use for many years.

The origin of the word *antenna* relative to wireless apparatus is attributed to Italian radio pioneer Guglielmo Marconi. In the summer of 1895, Marconi began testing his wireless system outdoors on his father's estate near Bologna and soon began to experiment with long wire "aerials". Marconi discovered that by raising the "aerial" wire above the ground and connecting the other side of his transmitter to ground, the transmission range was increased.[5] Soon he was able to transmit signals over a hill, a distance of approximately 2.4 kilometres (1.5 mi).[6] In Italian a tent pole is known as *l'antenna centrale,* and the pole with the wire was simply called *l'antenna.* Until then wireless radiating transmitting and receiving elements were known simply as aerials or terminals.

Because of his prominence, Marconi's use of the word *antenna* (Italian for *pole*) spread among wireless researchers, and later to the general public.[7][8][9]

In common usage, the word *antenna* may refer broadly to an entire assembly including support structure, enclosure (if any), etc. in addition to the actual functional components. Especially at microwave frequencies, a receiving antenna may include not only the actual electrical antenna but an integrated preamplifier or mixer.

An antenna, in converting radio waves to electrical signals or vice versa, is a form of transducer.[10]

Overview

Antennas are required by any radio receiver or transmitter to couple its electrical connection to the electromagnetic field. Radio waves are electromagnetic waves which carry signals through the air (or through space) at the speed of light with almost no transmission loss. Radio transmitters and receivers are used to convey signals (information) in systems including broadcast (audio) radio, television, mobile telephones, Wi-Fi (WLAN) data networks, trunk lines and point-to-point communications links (telephone, data networks), satellite links, many remote controlled devices such as garage door openers, and wireless

remote sensors, among many others. Radio waves are also used directly for measurements in technologies including radar, GPS, and radio astronomy. In each and every case, the transmitters and receivers involved require antennas, although these are sometimes hidden (such as the antenna inside an AM radio or inside a laptop computer equipped with Wi-Fi).


Antennas of the Atacama Large Millimeter submillimeter Array.[11]


Whip antenna on car, common example of an omnidirectional antenna

According to their applications and technology available, antennas generally fall in one of two categories:

1. Omnidirectional or only weakly directional antennas which receive or radiate more or less in all directions. These are employed when the relative position of the other station is unknown or arbitrary. They are also used at lower frequencies where a directional antenna would be too large, or simply to cut costs in applications where a directional antenna isn't required.
2. Directional or *beam* antennas which are intended to preferentially radiate or receive in a particular direction or directional pattern.

In common usage "omnidirectional" usually refers to all horizontal directions, typically with reduced performance in the direction of the sky or the ground (a truly isotropic radiator is not even possible). A "directional" antenna usually is intended to maximize its coupling to the electromagnetic field in the direction of the other station, or sometimes to cover a particular sector such as a 120° horizontal fan pattern in the case of a panel antenna at a cell site.

One example of omnidirectional antennas is the very common *vertical antenna* or whip antenna consisting of a metal rod (often, but not always, a quarter of a wavelength long). A dipole antenna is similar but consists of two such conductors extending in opposite directions, with a total length that is often, but not always, a half of a wavelength long. Dipoles are typically oriented horizontally in which case they are weakly directional: signals are reasonably well radiated toward or received from all directions with the exception of the direction along the conductor itself; this region is called the antenna blind cone or null.


Half-wave dipole antenna

Both the vertical and dipole antennas are simple in construction and relatively inexpensive. The dipole antenna, which is the basis for most antenna designs, is a balanced component, with equal but opposite voltages and currents applied at its two terminals through a balanced transmission line (or to a coaxial transmission line through a so-called balun). The vertical antenna, on the other hand, is a *monopole* antenna. It is typically connected to the inner conductor of a coaxial transmission line (or a matching network); the shield of the transmission line is connected to ground. In this way, the ground (or any large conductive surface) plays the role of the second conductor of a dipole, thereby forming a complete circuit. Since monopole antennas rely on a conductive ground, a so-called grounding structure may be employed to provide a better ground contact to the earth or which itself acts as a ground plane to perform that function regardless of (or in absence of) an actual contact with the earth.

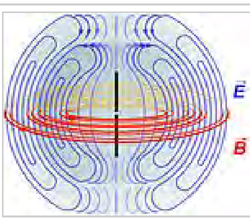


Diagram of the electric fields *(blue)* and magnetic fields *(red)* radiated by a dipole antenna *(black rods)* during transmission.

Antennas more complex than the dipole or vertical designs are usually intended to increase the directivity and consequently the gain of the antenna. This can be accomplished in many different ways leading to a plethora of antenna designs. The vast majority of designs are fed with a balanced line (unlike a monopole antenna) and are based on the dipole antenna with additional components (or *elements*) which increase its directionality. Antenna "gain" in this instance describes the concentration of radiated power into a particular solid angle of space, as opposed to the spherically uniform radiation of the ideal radiator. The increased power in the desired direction is at the expense of that in the undesired directions. Power is conserved, and there is no net power increase over that delivered from the power source (the transmitter.)

For instance, a phased array consists of two or more simple antennas which are connected together through an electrical network. This often involves a number of parallel dipole antennas with a certain spacing. Depending on the relative phase introduced by the network, the same combination of dipole antennas can operate as a "broadside array" (directional normal to a line connecting the

elements) or as an "end-fire array" (directional along the line connecting the elements). Antenna arrays may employ any basic (omnidirectional or weakly directional) antenna type, such as dipole, loop or slot antennas. These elements are often identical.

However a log-periodic dipole array consists of a number of dipole elements of *different* lengths in order to obtain a somewhat directional antenna having an extremely wide bandwidth: these are frequently used for television reception in fringe areas. The dipole antennas composing it are all considered "active elements" since they are all electrically connected together (and to the transmission line). On the other hand, a superficially similar dipole array, the Yagi-Uda Antenna (or simply "Yagi"), has only one dipole element with an electrical connection; the other so-called parasitic elements interact with the electromagnetic field in order to realize a fairly directional antenna but one which is limited to a rather narrow bandwidth. The Yagi antenna has similar looking parasitic dipole elements but which act differently due to their somewhat different lengths. There may be a number of so-called "directors" in front of the active element in the direction of propagation, and usually a single (but possibly more) "reflector" on the opposite side of the active element.

Greater directionality can be obtained using beam-forming techniques such as a parabolic reflector or a horn. Since high directivity in an antenna depends on it being large compared to the wavelength, narrow beams of this type are more easily achieved at UHF and microwave frequencies.

At low frequencies (such as AM broadcast), arrays of vertical towers are used to achieve directionality [12] and they will occupy large areas of land. For reception, a long Beverage antenna can have significant directivity. For non directional portable use, a short vertical antenna or small loop antenna works well, with the main design challenge being that of impedance matching. With a vertical antenna a *loading coil* at the base of the antenna may be employed to cancel the reactive component of impedance; small loop antennas are tuned with parallel capacitors for this purpose.

An antenna lead-in is the transmission line (or *feed line*) which connects the antenna to a transmitter or receiver. The *antenna feed* may refer to all components connecting the antenna to the transmitter or receiver, such as an impedance matching network in addition to the transmission line. In a so-called aperture antenna, such as a horn or parabolic dish, the "feed" may also refer to a basic antenna inside the entire system (normally at the focus of the parabolic dish or at the throat of a horn) which could be considered the one active element in that antenna system. A microwave antenna may also be fed directly from a waveguide in place of a (conductive) transmission line.


Cell phone base station antennas

An antenna counterpoise or ground plane is a structure of conductive material which improves or substitutes for the ground. It may be connected to or insulated from the natural ground. In a monopole antenna, this aids in the function of the natural ground, particularly where variations (or limitations) of the characteristics of the natural ground interfere with its proper function. Such a structure is normally connected to the return connection of an unbalanced transmission line such as the shield of a coaxial cable.

An electromagnetic wave *refractor* in some aperture antennas is a component which due to its shape and position functions to selectively delay or advance portions of the electromagnetic wavefront passing through it. The refractor alters the spatial characteristics of the wave on one side relative to the other side. It can, for instance, bring the wave to a focus or alter the wave front in other ways, generally in order to maximize the directivity of the antenna system. This is the radio equivalent of an optical lens.

An antenna coupling network is a passive network (generally a combination of inductive and capacitive circuit elements) used for impedance matching in between the antenna and the transmitter or receiver. This may be used to improve the standing wave ratio in order to minimize losses in the transmission line and to present the transmitter or receiver with a standard resistive impedance that it expects to see for optimum operation.

Reciprocity

It is a fundamental property of antennas that the electrical characteristics of an antenna described in the next section, such as gain, radiation pattern, impedance, bandwidth, resonant frequency and polarization, are the same whether the antenna is transmitting or receiving.[13][14] For example, the "*receiving pattern*" (sensitivity as a function of direction) of an antenna when used for reception is identical to the radiation pattern of the antenna when it is *driven* and functions as a radiator. This is a

consequence of the reciprocity theorem of electromagnetics.[14] Therefore, in discussions of antenna properties no distinction is usually made between receiving and transmitting terminology, and the antenna can be viewed as either transmitting or receiving, whichever is more convenient.

A necessary condition for the aforementioned reciprocity property is that the materials in the antenna and transmission medium are linear and reciprocal. *Reciprocal* (or *bilateral*) means that the material has the same response to an electric current or magnetic field in one direction, as it has to the field or current in the opposite direction. Most materials used in antennas meet these conditions, but some microwave antennas use high-tech components such as isolators and circulators, made of nonreciprocal materials such as ferrite.[13][14] These can be used to give the antenna a different behavior on receiving than it has on transmitting,[13] which can be useful in applications like radar.

Characteristics

Antennas are characterized by a number of performance measures which a user would be concerned with in selecting or designing an antenna for a particular application. Chief among these relate to the directional characteristics (as depicted in the antenna's *radiation pattern*) and the resulting *gain*. Even in omnidirectional (or weakly directional) antennas, the gain can often be increased by concentrating more of its power in the horizontal directions, sacrificing power radiated toward the sky and ground. The antenna's power gain (or simply "gain") also takes into account the antenna's efficiency, and is often the primary figure of merit.

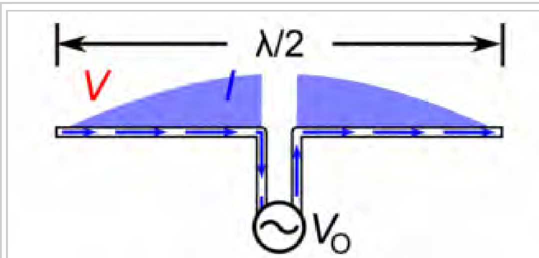
Resonant antennas are expected to be used around a particular *resonant frequency*; an antenna must therefore be built or ordered to match the frequency range of the intended application. A particular antenna design will present a particular feedpoint impedance. While this may affect the choice of an antenna, an antenna's impedance can also be adapted to the desired impedance level of a system using a matching network while maintaining the other characteristics (except for a possible loss of efficiency).

Although these parameters can be measured in principle, such measurements are difficult and require very specialized equipment. Beyond tuning a transmitting antenna using an SWR meter, the typical user will depend on theoretical predictions based on the antenna design or on claims of a vendor.

An antenna transmits and receives radio waves with a particular polarization which can be reoriented by tilting the axis of the antenna in many (but not all) cases. The physical size of an antenna is often a practical issue, particularly at lower frequencies (longer wavelengths). Highly directional antennas need to be significantly larger than the wavelength. Resonant antennas usually use a linear conductor (or *element*), or pair of such elements, each of which is about a quarter of the wavelength in length (an odd multiple of quarter wavelengths will also be resonant). Antennas that are required to be small compared to the wavelength sacrifice efficiency and cannot be very directional. Fortunately at higher frequencies (UHF, microwaves) trading off performance to obtain a smaller physical size is usually not required.

Resonant antennas

The majority of antenna designs are based on the *resonance* principle. This relies on the behaviour of moving electrons, which reflect off surfaces where the dielectric constant changes, in a fashion similar to the way light reflects when optical properties change. In these designs, the reflective surface is created by the end of a conductor, normally a thin metal wire or rod, which in the simplest case has a *feed point* at one end where it is connected to a transmission line. The conductor, or *element*, is aligned with the electrical field of the desired signal, normally meaning it is perpendicular to the line from the antenna to the source (or receiver in the case of a broadcast antenna).[15]



Standing waves on a half wave dipole driven at its resonant frequency. The waves are shown graphically by bars of color (red for voltage, *V* and blue for current, *I*) whose width is proportional to the amplitude of the quantity at that point on the antenna.

The radio signal's electrical component induces a voltage in the conductor. This causes an electrical current to begin flowing in the direction of the signal's instantaneous field. When the resulting current reaches the end of the conductor, it reflects, which is equivalent to a 180 degree change in phase. If the conductor is ¼ of a wavelength

long, current from the feed point will undergo 90 degree phase change by the time it reaches the end of the conductor, reflect through 180 degrees, and then another 90 degrees as it travels back. That means it has undergone a total 360 degree phase change, returning it to the original signal. The current in the element thus adds to the current being created from the source at that instant. This process creates a standing wave in the conductor, with the maximum current at the feed.[16]

The ordinary half-wave dipole is probably the most widely used antenna design. This consists of two $\frac{1}{4}$-wavelength elements arranged end-to-end, and lying along essentially the same axis (or *collinear*), each feeding one side of a two-conductor transmission wire. The physical arrangement of the two elements places them 180 degrees out of phase, which means that at any given instant one of the elements is driving current into the transmission line while the other is pulling it out. The monopole antenna is essentially one half of the half-wave dipole, a single $\frac{1}{4}$-wavelength element with the other side connected to ground or an equivalent ground plane (or *counterpoise*). Monopoles, which are one-half the size of a dipole, are common for long-wavelength radio signals where a dipole would be impractically large. Another common design is the folded dipole, which is essentially two dipoles placed side-by-side and connected at their ends to make a single one-wavelength antenna.

The standing wave forms with this desired pattern at the design frequency, f_0, and antennas are normally designed to be this size. However, feeding that element with $3f_0$ (whose wavelength is $\frac{1}{3}$ that of f_0) will also lead to a standing wave pattern. Thus, an antenna element is *also* resonant when its length is $\frac{3}{4}$ of a wavelength. This is true for all odd multiples of $\frac{1}{4}$ wavelength. This allows some flexibility of design in terms of antenna lengths and feed points. Antennas used in such a fashion are known to be *harmonically operated*.[17]

Current and voltage distribution

The quarter-wave elements imitate a series-resonant electrical element due to the standing wave present along the conductor. At the resonant frequency, the standing wave has a current peak and voltage node (minimum) at the feed. In electrical terms, this means the element has minimum reactance, generating the maximum current for minimum voltage. This is the ideal situation, because it produces the maximum output for the minimum input, producing the highest possible efficiency. Contrary to an ideal (lossless) series-resonant circuit, a finite resistance remains (corresponding to the relatively small voltage at the feed-point) due to the antenna's radiation resistance as well as any actual electrical losses.

Recall that a current will reflect when there are changes in the electrical properties of the material. In order to efficiently send the signal into the transmission line, it is important that the transmission line has the same impedance as the elements, otherwise some of the signal will be reflected back into the antenna. This leads to the concept of impedance matching, the design of the overall system of antenna and transmission line so the impedance is as close as possible, thereby reducing these losses. Impedance matching between antennas and transmission lines is commonly handled through the use of a balun, although other solutions are also used in certain roles. An important measure of this basic concept is the standing wave ratio, which measures the magnitude of the reflected signal.

Consider a half-wave dipole designed to work with signals 1 m wavelength, meaning the antenna would be approximately 50 cm across. If the element has a length-to-diameter ratio of 1000, it will have an inherent resistance of about 63 ohms. Using the appropriate transmission wire or balun, we match that resistance to ensure minimum signal loss. Feeding that antenna with a current of 1 ampere will require 63 volts of RF, and the antenna will radiate 63 watts (ignoring losses) of radio frequency power. Now consider the case when the antenna is fed a signal with a wavelength of 1.25 m; in this case the reflected current would arrive at the feed out-of-phase with the signal, causing the net current to drop while the voltage remains the same. Electrically this appears to be a very high impedance. The antenna and transmission line no longer have the same impedance, and the signal will be reflected back into the antenna, reducing output. This could be addressed by changing the matching system between the antenna and transmission line, but that solution only works well at the new design frequency.

The end result is that the resonant antenna will efficiently feed a signal into the transmission line only when the source signal's frequency is close to that of the design frequency of the antenna, or one of the resonant multiples. This makes resonant antenna designs inherently narrowband, and they are most commonly used with a single target signal. They are particularly common on radar systems, where the same antenna is used for both broadcast and reception, or for radio and television *broadcasts*, where the antenna is working with a single frequency. They are less commonly used for reception where multiple channels are present, in which case additional modifications are used to increase the bandwidth, or entirely different antenna designs are used.

Electrically short antennas

It is possible to use simple impedance matching concepts to allow the use of monopole or dipole antennas substantially shorter than the ¼ or ½ wavelength, respectively, at which they are resonant. As these antennas are made shorter (for a given frequency) their impedance becomes dominated by a series capacitive (negative) reactance; by adding a series inductance with the opposite (positive) reactance – a so-called loading coil – the antenna's reactance may be cancelled leaving only a pure resistance. Sometimes the resulting (lower) electrical resonant frequency of such a system (antenna plus matching network) is described using the concept of *electrical length*, so an antenna used at a lower frequency than its resonant frequency is called an *electrically short antenna*.

For example, at 30 MHz (10 m wavelength) a true resonant ¼ wavelength monopole would be almost 2.5 meters long, and using an antenna only 1.5 meters tall would require the addition of a loading coil. Then it may be said that the coil has lengthened the antenna to achieve an electrical length of 2.5 meters. However, the resulting resistive impedance achieved will be quite a bit lower than that of a true ¼ wave (resonant) monopole, often requiring further impedance matching (a transformer) to the desired transmission line. For ever shorter antennas (requiring greater "electrical lengthening") the radiation resistance plummets (approximately according to the square of the antenna length), so that the mismatch due to a net reactance away from the electrical resonance worsens. Or one could as well say that the equivalent resonant circuit of the antenna system has a higher Q factor and thus a reduced bandwidth, which can even become inadequate for the transmitted signal's spectrum. Resistive losses due to the loading coil, relative to the decreased radiation resistance, entail a reduced electrical efficiency, which can be of great concern for a transmitting antenna, but bandwidth is the major factor that sets the size of antennas at 1 MHz and lower frequencies.

Arrays and reflectors

The amount of signal received from a distant transmission source is essentially geometric in nature due to the inverse-square law, and this leads to the concept of *effective area*. This measures the performance of an antenna by comparing the amount of power it generates to the amount of power in the original signal, measured in terms of the signal's power density in Watts per square metre. A half-wave dipole has an effective area of 0.13 λ^2. If more performance is needed, one cannot simply make the antenna larger. Although this would intercept more energy from the signal, due to the considerations above, it would decrease the output significantly due to it moving away from the resonant length. In roles where higher performance is needed, designers often use multiple elements combined together.

Rooftop television Yagi-Uda antennas like these are widely used at VHF and UHF frequencies.

Returning to the basic concept of current flows in a conductor, consider what happens if a half-wave dipole is not connected to a feed point, but instead shorted out. Electrically this forms a single $\frac{1}{2}$-wavelength element. But the overall current pattern is the same; the current will be zero at the two ends, and reach a maximum in the center. Thus signals near the design frequency will continue to create a standing wave pattern. Any varying electrical current, like the standing wave in the element, will radiate a signal. In this case, aside from resistive losses in the element, the rebroadcast signal will be significantly similar to the original signal in both magnitude and shape. If this element is placed so its signal reaches the main dipole in-phase, it will reinforce the original signal, and increase the current in the dipole. Elements used in this way are known as *passive elements*.

A Yagi-Uda array uses passive elements to greatly increase gain. It is built along a support boom that is pointed toward the signal, and thus sees no induced signal and does not contribute to the antenna's operation. The end closer to the source is referred to as the front. Near the rear is a single active element, typically a half-wave dipole or folded dipole. Passive elements are arranged in front (*directors*) and behind (*reflectors*) the active element along the boom. The Yagi has the inherent quality that it becomes increasingly directional, and thus has higher gain, as the number of elements increases. However, this also makes it increasingly sensitive to changes in frequency; if the signal frequency changes, not only does the active element receive less energy directly, but all of the passive elements adding to that signal also decrease their output as well and their signals no longer reach the active element in-phase.

It is also possible to use multiple active elements and combine them together with transmission lines to produce a similar system where the phases add up to reinforce the output. The antenna array and very similar reflective array antenna consist of multiple elements, often half-wave dipoles, spaced out on a plane and wired together with transmission lines with specific phase lengths to produce a single in-phase signal at the output. The log-periodic antenna is a more complex design that uses multiple in-line elements similar in appearance to the Yagi-Uda but using transmission lines between the elements to produce the output.

Reflection of the original signal also occurs when it hits an extended conductive surface, in a fashion similar to a mirror. This effect can also be used to increase signal through the use of a *reflector*, normally placed behind the active element and spaced so the reflected signal reaches the element in-phase. Generally the reflector will remain highly reflective even if it is not solid; gaps less than $^1/_{10}$ generally have little effect on the outcome. For this reason, reflectors often take the form of wire meshes or rows of passive elements, which makes them lighter and less subject to wind. The parabolic reflector is perhaps the best known example of a reflector-based antenna, which has an effective area far greater than the active element alone.

Bandwidth

Although a resonant antenna has a purely resistive feed-point impedance at a particular frequency, many (if not most) applications require using an antenna over a range of frequencies. The frequency range or *bandwidth* over which an antenna functions well can be very wide (as in a log-periodic antenna) or narrow (in a resonant antenna); outside this range the antenna impedance becomes a poor match to the transmission line and transmitter (or receiver). Also in the case of the Yagi-Uda and other end-fire arrays, use of the antenna well away from its design frequency affects its radiation pattern, reducing its directive gain; the usable bandwidth is then limited regardless of impedance matching.

Except for the latter concern, the resonant frequency of an antenna system can always be altered by adjusting a suitable matching network. This is most efficiently accomplished using a matching network at the site of the antenna, since simply adjusting a matching network at the transmitter (or receiver) would leave the transmission line with a poor standing wave ratio.

Instead, it is often desired to have an antenna whose impedance does not vary so greatly over a certain bandwidth. It turns out that the amount of reactance seen at the terminals of a resonant antenna when the frequency is shifted, say, by 5%, depends very much on the diameter of the conductor used. A long thin wire used as a half-wave dipole (or quarter wave monopole) will have a reactance significantly greater than the resistive impedance it has at resonance, leading to a poor match and generally unacceptable performance. Making the element using a tube of a diameter perhaps 1/50 of its length, however, results in a reactance at this altered frequency which is not so great, and a much less serious mismatch and effect on the antenna's net performance. Thus rather thick tubes are often used for the elements; these also have reduced parasitic resistance (loss).

Rather than just using a thick tube, there are similar techniques used to the same effect such as replacing thin wire elements with *cages* to simulate a thicker element. This widens the bandwidth of the resonance. On the other hand, it is desired for amateur radio antennas to operate at several bands which are widely separated from each other (but not in between). This can often be accomplished simply by connecting elements resonant at those different frequencies in parallel. Most of the transmitter's power will flow into the resonant element while the others present a high (reactive) impedance, thus drawing little current from the same voltage. Another popular solution uses so-called *traps* consisting of parallel resonant circuits which are strategically placed in breaks along each antenna element. When used at one particular frequency band the trap presents a very high impedance (parallel resonance) effectively truncating the element at that length, making it a proper resonant antenna. At a lower frequency the trap allows the full length of the element to be employed, albeit with a shifted resonant frequency due to the inclusion of the trap's net reactance at that lower frequency.

The bandwidth characteristics of a resonant antenna element can be characterized according to its Q, just as one uses to characterize the sharpness of an L-C resonant circuit. A common mistake is to assume that there is an advantage in an antenna having a high Q (the so-called "quality factor"). In the context of electronic circuitry a low Q generally signifies greater loss (due to unwanted resistance) in a resonant L-C circuit, and poorer receiver selectivity. However this understanding does not apply to resonant antennas where the resistance involved is the radiation resistance, a desired quantity which removes energy from the resonant element in order to radiate it (the purpose of an antenna, after all!). The Q of an L-C-R circuit is defined as the ratio of the inductor's (or capacitor's) reactance to the resistance, so for a certain radiation resistance (the radiation resistance at resonance does not vary greatly with diameter) the greater reactance off-resonance causes the poorer bandwidth of an antenna employing a very thin conductor. The Q of such a narrowband antenna can be as high as 15. On the other hand, the reactance at the same off-resonant frequency of one using thick elements is much less, consequently resulting in a Q as low as 5. These two antennas may perform equivalently at the resonant frequency, but the second antenna will perform over a bandwidth 3 times as wide as the antenna consisting of a thin conductor.

Antennas for use over much broader frequency ranges are achieved using further techniques. Adjustment of a matching network can, in principle, allow for any antenna to be matched at any frequency. Thus the loop antenna built into most AM broadcast (medium wave) receivers has a very narrow bandwidth, but is tuned using a parallel capacitance which is adjusted according to the receiver tuning. On the other hand, log-periodic antennas are *not* resonant at any frequency but can be built to attain similar characteristics (including feedpoint impedance) over any frequency range. These are therefore commonly used (in the form of directional log-periodic dipole arrays) as television antennas.

Gain

Gain is a parameter which measures the degree of directivity of the antenna's radiation pattern. A high-gain antenna will radiate most of its power in a particular direction, while a low-gain antenna will radiate over a wider angle. The *antenna gain*, or *power gain* of an antenna is defined as the ratio of the intensity (power per unit surface area) I radiated by the antenna in the direction of its maximum output, at an arbitrary distance, divided by the intensity I_{iso} radiated at the same distance by a hypothetical isotropic antenna which radiates equal power in all directions. This dimensionless ratio is usually expressed logarithmically in decibels, these units are called "decibels-isotropic" (dBi)

$$G_{\text{dBi}} = 10 \log \frac{I}{I_{\text{iso}}}$$

A second unit used to measure gain is the ratio of the power radiated by the antenna to the power radiated by a half-wave dipole antenna I_{dipole}; these units are called "decibels-dipole" (dBd)

$$G_{\text{dBd}} = 10 \log \frac{I}{I_{\text{dipole}}}$$

Since the gain of a half-wave dipole is 2.15 dBi and the logarithm of a product is additive, the gain in dBi is just 2.15 decibels greater than the gain in dBd

$$G_{\text{dBi}} = G_{\text{dBd}} + 2.15$$

High-gain antennas have the advantage of longer range and better signal quality, but must be aimed carefully at the other antenna. An example of a high-gain antenna is a parabolic dish such as a satellite television antenna. Low-gain antennas have shorter range, but the orientation of the antenna is relatively unimportant. An example of a low-gain antenna is the whip antenna found on portable radios and cordless phones. Antenna gain should not be confused with amplifier gain, a separate parameter measuring the increase in signal power due to an amplifying device.

Effective area or aperture

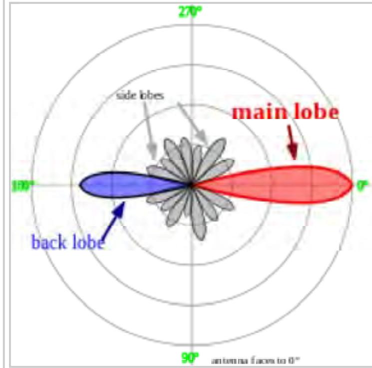
The *effective area* or effective aperture of a receiving antenna expresses the portion of the power of a passing electromagnetic wave which it delivers to its terminals, expressed in terms of an equivalent area. For instance, if a radio wave passing a given location has a flux of 1 pW / m^2 (10^{-12} watts per square meter) and an antenna has an effective area of 12 m^2, then the antenna would deliver 12 pW of RF power to the receiver (30 microvolts rms at 75 ohms). Since the receiving antenna is not equally sensitive to signals received from all directions, the effective area is a function of the direction to the source.

Due to reciprocity (discussed above) the gain of an antenna used for transmitting must be proportional to its effective area when used for receiving. Consider an antenna with no loss, that is, one whose electrical efficiency is 100%. It can be shown that its effective area averaged over all directions must be equal to $\lambda^2/4\pi$, the wavelength squared divided by 4π. Gain is defined such that the average gain over all directions for an antenna with 100% electrical efficiency is equal to 1. Therefore, the effective area A_{eff} in terms of the gain G in a given direction is given by:

$$A_{\text{eff}} = \frac{\lambda^2}{4\pi} G$$

For an antenna with an efficiency of less than 100%, both the effective area and gain are reduced by that same amount. Therefore, the above relationship between gain and effective area still holds. These are thus two different ways of expressing the same quantity. A_{eff} is especially convenient when computing the power that would be received by an antenna of a specified gain, as illustrated by the above example.

Radiation pattern



Polar plots of the horizontal cross sections of a (virtual) Yagi-Uda-antenna. Outline connects points with 3db field power compared to an ISO emitter.

The radiation pattern of an antenna is a plot of the relative field strength of the radio waves emitted by the antenna at different angles. It is typically represented by a three-dimensional graph, or polar plots of the horizontal and vertical cross sections. The pattern of an ideal isotropic antenna, which radiates equally in all directions, would look like a sphere. Many nondirectional antennas, such as monopoles and dipoles, emit equal power in all horizontal directions, with the power dropping off at higher and lower angles; this is called an omnidirectional pattern and when plotted looks like a torus or donut.

The radiation of many antennas shows a pattern of maxima or "*lobes*" at various angles, separated by "*nulls*", angles where the radiation falls to zero. This is because the radio waves emitted by different parts of the antenna typically interfere, causing maxima at angles where the radio waves arrive at distant points in phase, and zero radiation at other angles where the radio waves arrive out of phase. In a directional antenna designed to project radio waves in a particular direction, the lobe in that direction is designed larger than the others and is called the "*main lobe*". The other lobes usually represent unwanted radiation and are called "*sidelobes*". The axis through the main lobe is called the "*principal axis*" or "*boresight axis*".

Field regions

The space surrounding an antenna can be divided into three concentric regions: the reactive near-field, the radiating near-field (Fresnel region) and the far-field (Fraunhofer) regions. These regions are useful to identify the field structure in each, although there are no precise boundaries.

In the far-field region, we are far enough from the antenna to neglect its size and shape. We can assume that the electromagnetic wave is purely a radiating plane wave (electric and magnetic fields are in phase and perpendicular to each other and to the direction of propagation). This simplifies the mathematical analysis of the radiated field.

Impedance

As an electro-magnetic wave travels through the different parts of the antenna system (radio, feed line, antenna, free space) it may encounter differences in impedance (E/H, V/I, etc.). At each interface, depending on the impedance match, some fraction of the wave's energy will reflect back to the source,[18] forming a standing wave in the feed line. The ratio of maximum power to minimum power in the wave can be measured and is called the standing wave ratio (SWR). A SWR of 1:1 is ideal. A SWR of 1.5:1 is considered to be marginally acceptable in low power applications where power loss is more critical, although an SWR as high as 6:1 may still be usable with the right equipment. Minimizing impedance differences at each interface (impedance matching) will reduce SWR and maximize power transfer through each part of the antenna system.

Complex impedance of an antenna is related to the electrical length of the antenna at the wavelength in use. The impedance of an antenna can be matched to the feed line and radio by adjusting the impedance of the feed line, using the feed line as an impedance transformer. More commonly, the impedance is adjusted at the load (see below) with an antenna tuner, a balun, a matching transformer, matching networks composed of inductors and capacitors, or matching sections such as the gamma match.

Efficiency

Efficiency of a transmitting antenna is the ratio of power actually radiated (in all directions) to the power absorbed by the antenna terminals. The power supplied to the antenna terminals which is not radiated is converted into heat. This is usually through loss resistance in the antenna's conductors, but can also be due to dielectric or magnetic core losses in antennas (or antenna systems) using such components. Such loss effectively robs power from the transmitter, requiring a stronger transmitter in order to transmit a signal of a given strength.

For instance, if a transmitter delivers 100 W into an antenna having an efficiency of 80%, then the antenna will radiate 80 W as radio waves and produce 20 W of heat. In order to radiate 100 W of power, one would need to use a transmitter capable of supplying 125 W to the antenna. Note that antenna efficiency is a separate issue from impedance matching, which may also

reduce the amount of power radiated using a given transmitter. If an SWR meter reads 150 W of incident power and 50 W of reflected power, that means that 100 W have actually been absorbed by the antenna (ignoring transmission line losses). How much of that power has actually been radiated cannot be directly determined through electrical measurements at (or before) the antenna terminals, but would require (for instance) careful measurement of field strength. Fortunately the loss resistance of antenna conductors such as aluminum rods can be calculated and the efficiency of an antenna using such materials predicted.

However loss resistance will generally affect the feedpoint impedance, adding to its resistive (real) component. That resistance will consist of the sum of the radiation resistance R_r and the loss resistance R_{loss}. If an rms current I is delivered to the terminals of an antenna, then a power of I^2R_r will be radiated and a power of I^2R_{loss} will be lost as heat. Therefore, the efficiency of an antenna is equal to $R_r / (R_r + R_{loss})$. Of course only the total resistance $R_r + R_{loss}$ can be directly measured.

According to reciprocity, the efficiency of an antenna used as a receiving antenna is identical to the efficiency as defined above. The power that an antenna will deliver to a receiver (with a proper impedance match) is reduced by the same amount. In some receiving applications, the very inefficient antennas may have little impact on performance. At low frequencies, for example, atmospheric or man-made noise can mask antenna inefficiency. For example, CCIR Rep. 258-3 indicates man-made noise in a residential setting at 40 MHz is about 28 dB above the thermal noise floor. Consequently, an antenna with a 20 dB loss (due to inefficiency) would have little impact on system noise performance. The loss within the antenna will affect the intended signal and the noise/interference identically, leading to no reduction in signal to noise ratio (SNR).

This is fortunate, since antennas at lower frequencies which are not rather large (a good fraction of a wavelength in size) are inevitably inefficient (due to the small radiation resistance R_r of small antennas). Most AM broadcast radios (except for car radios) take advantage of this principle by including a small loop antenna for reception which has an extremely poor efficiency. Using such an inefficient antenna at this low frequency (530–1650 kHz) thus has little effect on the receiver's net performance, but simply requires greater amplification by the receiver's electronics. Contrast this tiny component to the massive and very tall towers used at AM broadcast stations for transmitting at the very same frequency, where every percentage point of reduced antenna efficiency entails a substantial cost.

The definition of antenna gain or *power gain* already includes the effect of the antenna's efficiency. Therefore, if one is trying to radiate a signal toward a receiver using a transmitter of a given power, one need only compare the gain of various antennas rather than considering the efficiency as well. This is likewise true for a receiving antenna at very high (especially microwave) frequencies, where the point is to receive a signal which is strong compared to the receiver's noise temperature. However, in the case of a directional antenna used for receiving signals with the intention of *rejecting* interference from different directions, one is no longer concerned with the antenna efficiency, as discussed above. In this case, rather than quoting the antenna gain, one would be more concerned with the *directive gain* which does *not* include the effect of antenna (in)efficiency. The directive gain of an antenna can be computed from the published gain divided by the antenna's efficiency.

Polarization

The *polarization* of an antenna refers to the orientation of the electric field (E-plane) of the radio wave with respect to the Earth's surface and is determined by the physical structure of the antenna and by its orientation; note that this designation is totally distinct from the antenna's directionality. Thus, a simple straight wire antenna will have one polarization when mounted vertically, and a different polarization when mounted horizontally. As a transverse wave, the magnetic field of a radio wave is at right angles to that of the electric field, but by convention, talk of an antenna's "polarization" is understood to refer to the direction of the electric field.

Reflections generally affect polarization. For radio waves, one important reflector is the ionosphere which can change the wave's polarization. Thus for signals received following reflection by the ionosphere (a skywave), a consistent polarization cannot be expected. For line-of-sight communications or ground wave propagation, horizontally or vertically polarized transmissions generally remain in about the same polarization state at the receiving location. Matching the receiving antenna's polarization to that of the transmitter can make a very substantial difference in received signal strength.

Polarization is predictable from an antenna's geometry, although in some cases it is not at all obvious (such as for the quad antenna). An antenna's linear polarization is generally along the direction (as viewed from the receiving location) of the antenna's currents when such a direction can be defined. For instance, a vertical whip antenna or Wi-Fi antenna vertically oriented will transmit and receive in the vertical polarization. Antennas with horizontal elements, such as most rooftop TV

antennas in the United States, are horizontally polarized (broadcast TV in the U.S. usually uses horizontal polarization). Even when the antenna system has a vertical orientation, such as an array of horizontal dipole antennas, the polarization is in the horizontal direction corresponding to the current flow. The polarization of a commercial antenna is an essential specification.

Polarization is the sum of the E-plane orientations over time projected onto an imaginary plane perpendicular to the direction of motion of the radio wave. In the most general case, polarization is elliptical, meaning that the polarization of the radio waves varies over time. Two special cases are linear polarization (the ellipse collapses into a line) as we have discussed above, and circular polarization (in which the two axes of the ellipse are equal). In linear polarization the electric field of the radio wave oscillates back and forth along one direction; this can be affected by the mounting of the antenna but usually the desired direction is either horizontal or vertical polarization. In circular polarization, the electric field (and magnetic field) of the radio wave rotates at the radio frequency circularly around the axis of propagation. Circular or elliptically polarized radio waves are designated as right-handed or left-handed using the "thumb in the direction of the propagation" rule. Note that for circular polarization, optical researchers use the opposite right hand rule from the one used by radio engineers.

It is best for the receiving antenna to match the polarization of the transmitted wave for optimum reception. Intermediate matchings will lose some signal strength, but not as much as a complete mismatch. A circularly polarized antenna can be used to equally well match vertical or horizontal linear polarizations. Transmission from a circularly polarized antenna received by a linearly polarized antenna (or vice versa) entails a 3 dB reduction in signal-to-noise ratio as the received power has thereby been cut in half.

Impedance matching

Maximum power transfer requires matching the impedance of an antenna system (as seen looking into the transmission line) to the complex conjugate of the impedance of the receiver or transmitter. In the case of a transmitter, however, the desired matching impedance might not correspond to the dynamic output impedance of the transmitter as analyzed as a source impedance but rather the design value (typically 50 ohms) required for efficient and safe operation of the transmitting circuitry. The intended impedance is normally resistive but a transmitter (and some receivers) may have additional adjustments to cancel a certain amount of reactance in order to "tweak" the match. When a transmission line is used in between the antenna and the transmitter (or receiver) one generally would like an antenna system whose impedance is resistive and near the characteristic impedance of that transmission line in order to minimize the standing wave ratio (SWR) and the increase in transmission line losses it entails, in addition to supplying a good match at the transmitter or receiver itself.

Antenna tuning generally refers to cancellation of any reactance seen at the antenna terminals, leaving only a resistive impedance which might or might not be exactly the desired impedance (that of the transmission line). Although an antenna may be designed to have a purely resistive feedpoint impedance (such as a dipole 97% of a half wavelength long) this might not be exactly true at the frequency that it is eventually used at. In some cases the physical length of the antenna can be "trimmed" to obtain a pure resistance. On the other hand, the addition of a series inductance or parallel capacitance can be used to cancel a residual capacitative or inductive reactance, respectively.

In some cases this is done in a more extreme manner, not simply to cancel a small amount of residual reactance, but to resonate an antenna whose resonance frequency is quite different from the intended frequency of operation. For instance, a "whip antenna" can be made significantly shorter than 1/4 wavelength long, for practical reasons, and then resonated using a so-called loading coil. This physically large inductor at the base of the antenna has an inductive reactance which is the opposite of the capacitative reactance that such a vertical antenna has at the desired operating frequency. The result is a pure resistance seen at feedpoint of the loading coil; unfortunately that resistance is somewhat lower than would be desired to match commercial coax.

So an additional problem beyond canceling the unwanted reactance is of matching the remaining resistive impedance to the characteristic impedance of the transmission line. In principle this can always be done with a transformer, however the turns ratio of a transformer is not adjustable. A general matching network with at least two adjustments can be made to correct both components of impedance. Matching networks using discrete inductors and capacitors will have losses associated with those components, and will have power restrictions when used for transmitting. Avoiding these difficulties, commercial antennas are generally designed with fixed matching elements or feeding strategies to get an approximate match to standard coax, such as 50 or 75 Ohms. Antennas based on the dipole (rather than vertical antennas) should include a balun in between the transmission line and antenna element, which may be integrated into any such matching network.

Another extreme case of impedance matching occurs when using a small loop antenna (usually, but not always, for receiving) at a relatively low frequency where it appears almost as a pure inductor. Resonating such an inductor with a capacitor at the frequency of operation not only cancels the reactance but greatly magnifies the very small radiation resistance of such a loop. This is implemented in most AM broadcast receivers, with a small ferrite loop antenna resonated by a capacitor which is varied along with the receiver tuning in order to maintain resonance over the AM broadcast band

Antenna types

Antennas can be classified in various ways. The list below groups together antennas under common operating principles, following the way antennas are classified in many engineering textbooks.[19][20][21]

Isotropic: An isotropic antenna (isotropic radiator) is a *hypothetical* antenna that radiates equal signal power in all directions. It is a mathematical model that is used as the base of comparison to calculate the gain of real antennas. No real antenna can have an isotropic radiation pattern. However *approximately* isotropic antennas, constructed with multiple elements, are used in antenna testing.

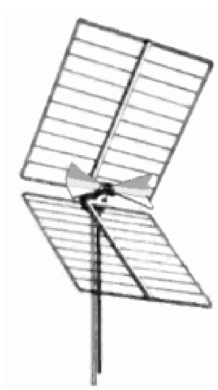
The first four groups below are usually resonant antennas; when driven at their resonant frequency their elements act as resonators. Waves of current and voltage bounce back and forth between the ends, creating standing waves along the elements.

Dipole

"Rabbit ears" dipole variant for VHF television reception

Yagi-Uda television antenna for analog channels 2-4, 47-68 MHz

Log-periodic dipole array covering 140-470 MHz



Corner reflector UHF TV antenna with "bowtie" dipole driven element

Two-element turnstile antenna for reception of weather satellite data, 137 MHz. Has circular polarization.

The dipole is the prototypical antenna on which a large class of antennas are based. A basic dipole antenna consists of two conductors (usually metal rods or wires) arranged symmetrically, with one side of the balanced feedline from the transmitter or receiver attached to each.[20][22] The most common type, the half-wave dipole, consists of two resonant elements just under a quarter wavelength long. This antenna radiates maximally in directions perpendicular to the antenna's axis, giving it a small directive gain of 2.15 dBi (practically the lowest directive gain of any antenna). Although half-wave dipoles are used alone as omnidirectional antennas, they are also a building block of many other more complicated directional antennas.

- *Yagi-Uda* - One of the most common directional antennas at HF, VHF, and UHF frequencies. Consists of multiple half wave dipole elements in a line, with a single driven element and multiple parasitic elements which serve to create a uni-directional or beam antenna. These typically have gains between 10 and 20 dBi depending on the number of elements used, and are very narrowband (with a usable bandwidth of only a few percent) though there are derivative designs which relax this limitation. Used for rooftop television antennas, point-to-point communication links, and long distance shortwave communication using skywave ("skip") reflection from the ionosphere.
- *Log-periodic dipole array* - Often confused with the Yagi-Uda, this consists of many dipole elements along a boom with gradually increasing lengths, all connected to the transmission line with alternating polarity. It is a directional antenna with a wide bandwidth. This makes it ideal for use as a rooftop television antenna, although its gain is much less than a Yagi of comparable size.
- *Turnstile* - Two dipole antennas mounted at right angles, fed with a phase difference of 90°. This antenna is unusual in that it radiates in *all* directions (no nodes in the radiation pattern), with horizontal polarization in directions coplaner with the elements, circular polarization normal to that plane, and elliptical polarization in other directions. Used for receiving signals from satellites, as circular polarization is transmitted by many satellites.
- *Corner reflector* - A directive antenna with moderate gain of about 8 dBi often used at UHF frequencies. Consists of a dipole mounted in front of two reflective metal screens joined at an angle, usually 90°. Used as a rooftop UHF television antenna and for point-to-point data links.
- *Patch (microstrip)* - A type of antenna with elements consisting of metal sheets mounted over a ground plane. Similar to dipole with gain of 6 - 9 dBi. Integrated into surfaces such as aircraft bodies. Their easy fabrication using PCB techniques have made them popular in modern wireless devices. Often used in arrays.

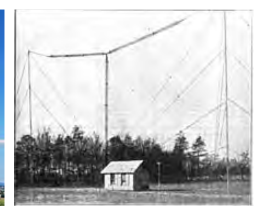
Monopole

Quarter-wave whip antenna on an FM radio for 88-108 MHz

Rubber Ducky antenna on UHF 446 MHz walkie talkie with rubber cover removed.

VHF ground plane antenna

Mast radiator antenna of medium wave AM radio station, Germany



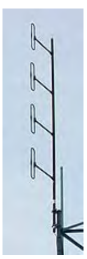
T antenna of amateur radio station, 80 ft high, used at 1.5 MHz.

Monopole antennas consist of a single conductor such as a metal rod, mounted over the ground or an artificial conducting surface (a so-called *ground plane*).[20][23] One side of the feedline from the receiver or transmitter is connected to the conductor, and the other side to ground and/or the artificial ground plane. The monopole is best understood as a dipole antenna in which one conductor is omitted; the radiation is generated as if the second arm of the dipole were present due to the effective image current seen as a reflection of the monopole from the ground. Since all of the equivalent dipole's radiation is concentrated in a half-space, the antenna has twice (3 dB increase of) the gain of a similar dipole, not considering losses in the ground plane.

The most common form is the quarter-wave monopole which is one-quarter of a wavelength long and has a gain of 5.12 dBi when mounted over a ground plane. Monopoles have an omnidirectional radiation pattern, so they are used for broad coverage of an area, and have vertical polarization. The ground waves used for broadcasting at low frequencies must be vertically polarized, so large vertical monopole antennas are used for broadcasting in the MF, LF, and VLF bands. Small monopoles are used as nondirectional antennas on portable radios in the HF, VHF, and UHF bands.

- *Whip* - Type of antenna used on mobile and portable radios in the VHF and UHF bands such as boom boxes, consists of a flexible rod, often made of telescoping segments.
  - *Rubber Ducky* - Most common antenna used on portable two way radios and cordless phones due to its compactness, consists of an electrically short wire helix. The helix adds inductance to cancel the capacitive reactance of the short radiator, making it resonant. Very low gain.
  - *Ground plane* - a whip antenna with several rods extending horizontally from base of whip attached to the ground side of the feedline. Since whips are mounted above ground, the horizontal rods form an artificial ground plane under the antenna to increase its gain. Used as base station antennas for land mobile radio systems such as police, ambulance and taxi dispatchers.
- *Mast radiator* - A radio tower in which the tower structure itself serves as the antenna. Common form of transmitting antenna for AM radio stations and other MF and LF transmitters. At its base the tower is usually, but not necessarily, mounted on a ceramic insulator to isolate it from the ground.
- *T and inverted L* - Consist of a long horizontal wire suspended between two towers with insulators, with a vertical wire hanging down from it, attached to a feedline to the receiver or transmitter. Used on LF and VLF bands. The vertical wire serves as the radiator. Since at these frequencies the vertical wire is electrically short, much shorter than a quarter wavelength, the horizontal wire(s) serve as a capacitive "hat" to increase the current in the vertical radiator, increasing the gain. Very narrow bandwidth, requires loading coil to tune out the capacitive reactance and make it resonant. Requires low resistance ground (electricity)
- *Inverted F* - Combines the advantages of the inverted-L antenna and the F-type antenna of, respectively, compactness and good matching. The antenna is grounded at the base and fed at some intermediate point. The position of the feed point determines the antenna impedance. Thus, matching can be achieved without the need for an extraneous matching network.
- *Umbrella* - Very large wire transmitting antennas used on VLF bands. Consists of a central mast radiator tower attached at the top to multiple wires extending out radially from the mast to ground, like a tent or umbrella, insulated at the ends. Extremely narrow bandwidth, requires large loading coil and low resistance counterpoise ground. Used for long range military communications.

Array



VHF collinear array of folded dipoles

Sector antennas *(white bars)* on cell phone tower. Collinear arrays of dipoles, these radiate a flat, fan-shaped beam.

108 MHz reflective array antenna of AN-270 radar used during WW2.

Reflective array UHF TV antenna, with bowtie dipoles to cover the UHF 470-890 MHz band

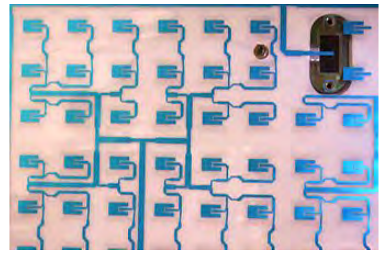
US Air Force PAVE PAWS phased array radar antenna for ballistic missile detection, Alaska. The two circular arrays are composed of thousands of crossed dipole antennas.

Batwing VHF television broadcasting antenna

Crossed-dipole FM radio broadcast antenna

Curtain array shortwave transmitting antenna, Austria. Wire dipoles suspended between towers

Turnstile antenna array used for satellite communication



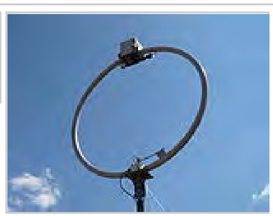
Flat microstrip array antenna for satellite TV reception.

Array antennas consist of multiple antennas working as a single antenna. Typically they consist of arrays of identical driven elements, usually dipoles fed in phase, giving increased gain over that of a single dipole.[20][24][25]

- *Collinear* - Consist of a number of dipoles in a vertical line. It is a high gain omnidirectional antenna, meaning more of the power is radiated in horizontal directions and less into the sky or ground and wasted. Gain of 8 to 10 dBi. Used as base station antennas for land mobile radio systems such as police, fire, ambulance, and taxi dispatchers, and sector antennas for cellular base stations.
- *Reflective array* - multiple dipoles in a two-dimensional array mounted in front of a flat reflecting screen. Used for radar and UHF television transmitting and receiving antennas.
- *Phased array* - A high gain antenna used at UHF and microwave frequencies which is electronically steerable. It consists of multiple dipoles in a two-dimensional array, each fed through an electronic phase shifter, with the phase shifters controlled by a computer control system. The beam can be instantly pointed in any direction over a wide angle in front of the antenna. Used for military radar and jamming systems.
- *Curtain array* - Large directional wire transmitting antenna used at HF by shortwave broadcasting stations. It consists of a vertical rectangular array of wire dipoles suspended in front of a flat reflector screen consisting of a vertical "curtain" of parallel wires, all supported between two metal towers. It radiates a horizontal beam of radio waves into the sky above the horizon, which is reflected by the ionosphere to Earth beyond the horizon
- *Batwing* or *superturnstile* - A specialized antenna used in television broadcasting consisting of perpendicular pairs of dipoles with radiators resembling bat wings. Multiple batwing antennas are stacked vertically on a mast to make VHF television broadcast antennas. Omnidirectional radiation pattern with high gain in horizontal directions. The batwing shape gives them wide bandwidth.
- *microstrip* - an array of patch antennas on a substrate fed by microstrip feedlines. Microwave antenna that can achieve large gains in compact space. Ease of fabrication by PCB techniques have made them popular in modern wireless devices. Beamwidth and polarization can be actively reconfigurable.

Loop

Loopstick antenna from an AM broadcast radio, about 4 in (10 cm) long. The antenna is inductive and, in conjunction with a variable capacitor, forms the tuned circuit at the input stage of the receiver.



Loop antenna for transmitting at high frequencies, 2m diameter

Separate loop antenna for AM radio

A two-element quad antenna used by an amateur radio station

Loop antennas consist of a loop (or coil) of wire.[20][26][27] Loops with circumference of a wavelength (or integer multiple of the wavelength) are resonant and act somewhat similarly to the half-wave dipole. However a loop small in comparison to the wavelength, also called a magnetic loop, performs quite differently. This antenna interacts directly with the magnetic field of

the radio wave, making it relatively insensitive to nearby electrical noise. However it has a very small radiation resistance, typically much smaller than the loss resistance, making it inefficient and thus undesirable for transmitting. They are used as receiving antennas at low frequencies, and also as direction finding antennas.

- *Ferrite (loopstick)* - These are used as the receiving antenna in most consumer AM radios operating in the medium wave broadcast band (and lower frequencies), a notable exception being car radios. Wire is coiled around a ferrite core which greatly increases the coil's inductance. Radiation pattern is maximum at directions normal to the ferrite stick.
- *Quad* - consists of multiple wire loops in a line with one functioning as the driven element, and the others as parasitic elements. Used as a directional antenna on the HF bands for shortwave communication.

Aperture

NASA Cassegrain parabolic spacecraft communication antenna, Australia. Uses X band, 8 – 12 GHz. Extremely high gain ~70 dBi.

Microwave horn antenna bandwidth 0.8–18 GHz

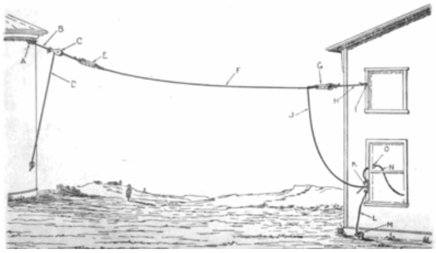
X band marine radar slot antenna on ship, 8 – 12 GHz.

Dielectric lens antenna used in millimeter wave radio telescope

Aperture antennas are the main type of directional antennas used at microwave frequencies and above.[20][28] They consist of a small dipole or loop feed antenna inside a three-dimensional guiding structure large compared to a wavelength, with an aperture to emit the radio waves. Since the antenna structure itself is nonresonant they can be used over a wide frequency range by replacing or tuning the feed antenna.

- *Parabolic* - The most widely used high gain antenna at microwave frequencies and above. Consists of a dish-shaped metal parabolic reflector with a feed antenna at the focus. It can have some of the highest gains of any antenna type, up to 60 dBi, but the dish must be large compared to a wavelength. Used for radar antennas, point-to-point data links, satellite communication, and radio telescopes
- *Horn* - Simple antenna with moderate gains of 15 to 25 dBi consists of a flaring metal horn attached to a waveguide. Used for applications such as radar guns, radiometers and as feed antennas for parabolic dishes.
- *Slot* - Consist of a waveguide with one or more slots cut in it to emit the microwaves. Linear slot antennas emit narrow fan-shaped beams. Used as UHF broadcast antennas and marine radar antennas.
- *Dielectric resonator* - consists of small ball or puck-shaped piece of dielectric material excited by aperture in waveguide Used at millimeter wave frequencies

Traveling wave



A typical random wire antenna for shortwave reception, strung between two buildings.

Quadrant antenna, similar to rhombic, at an Austrian shortwave broadcast station. Radiates horizontal beam at 5-9 MHz, 100 kW

Array of four axial-mode helical antennas used for satellite tracking, France

Unlike the above antennas, traveling wave antennas are nonresonant so they have inherently broad bandwidth.[20][29] They are typically wire antennas multiple wavelengths long, through which the voltage and current waves travel in one direction, instead of bouncing back and forth to form standing waves as in resonant antennas. They have linear polarization (except for the helical antenna). Unidirectional traveling wave antennas are terminated by a resistor at one end equal to the antenna's characteristic resistance, to absorb the waves from one direction. This makes them inefficient as transmitting antennas.

- *Random wire* - This describes the typical antenna used to receive shortwave radio, consisting of a random length of wire either strung outdoors between supports or indoors in a zigzag pattern along walls, connected to the receiver at one end. Can have complex radiation patterns with several lobes at angles to the wire.
- *Beverage* - Simplest unidirectional traveling wave antenna. Consists of a straight wire one to several wavelengths long, suspended near the ground, connected to the receiver at one end and terminated by a resistor equal to its characteristic impedance, 400 to 800Ω at the other end. Its radiation pattern has a main lobe at a shallow angle in the sky off the terminated end. It is used for reception of skywaves reflected off the ionosphere in long distance "skip" shortwave communication.
- *Rhombic* - Consists of four equal wire sections shaped like a rhombus. It is fed by a balanced feedline at one of the acute corners, and the two sides are connected to a resistor equal to the characteristic resistance of the antenna at the other. It has a main lobe in a horizontal direction off the terminated end of the rhombus. Used for skywave communication on shortwave bands.
- *Helical (axial mode)* - Consists of a wire in the shape of a helix mounted above a reflecting screen. It radiates circularly polarized waves in a beam off the end, with a typical gain of 15 dBi. It is used at VHF and UHF frequencies for communication with satellites and animal tracking transmitters, which use circular polarization because it is insensitive to the relative orientation of the antennas.
- *Leaky wave* - Microwave antennas consisting of a waveguide or coaxial cable with a slot or apertures cut in it so it radiates continuously along its length.

Effect of ground

Ground reflections is one of the common types of multipath.[30][31][32]

The radiation pattern and even the driving point impedance of an antenna can be influenced by the dielectric constant and especially conductivity of nearby objects. For a terrestrial antenna, the ground is usually one such object of importance. The antenna's height above the ground, as well as the electrical properties (permittivity and conductivity) of the ground, can then be important. Also, in the particular case of a monopole antenna, the ground (or an artificial ground plane) serves as the return connection for the antenna current thus having an additional effect, particularly on the impedance seen by the feed line.

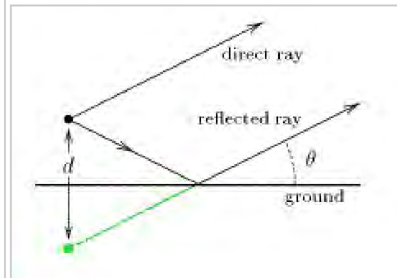
When an electromagnetic wave strikes a plane surface such as the ground, part of the wave is transmitted into the ground and part of it is reflected, according to the Fresnel coefficients. If the ground is a very good conductor then almost all of the wave is reflected (180° out of phase), whereas a ground modeled as a (lossy) dielectric can absorb a large amount of the wave's power. The power remaining in the reflected wave, and the phase shift upon reflection, strongly depend on the wave's angle of incidence and polarization. The dielectric constant and conductivity (or simply the complex dielectric constant) is dependent on the soil type and is a function of frequency.

For very low frequencies to high frequencies (<30 MHz), the ground behaves as a lossy dielectric,[33] Thus the ground is characterized both by a conductivity [34] and permittivity (dielectric constant) which can be measured for a given soil (but is influenced by fluctuating moisture levels) or can be estimated from certain maps. At lower frequencies the ground acts mainly as a good conductor, which AM middle wave broadcast (.5 - 1.6 MHz) antennas depend on.

At frequencies between 3 and 30 MHz, a large portion of the energy from a horizontally polarized antenna reflects off the ground, with almost total reflection at the grazing angles important for ground wave propagation. That reflected wave, with its phase reversed, can either cancel or reinforce the direct wave, depending on the antenna height in wavelengths and elevation angle (for a sky wave).

On the other hand, vertically polarized radiation is not well reflected by the ground except at grazing incidence or over very highly conducting surfaces such as sea water.[35] However the grazing angle reflection important for ground wave propagation, using vertical polarization, is *in phase* with the direct wave, providing a boost of up to 6 db, as is detailed below.

At VHF and above (>30 MHz) the ground becomes a poorer reflector. However it remains a good reflector especially for horizontal polarization and grazing angles of incidence. That is important as these higher frequencies usually depend on horizontal line-of-sight propagation (except for satellite communications), the ground then behaving almost as a mirror.



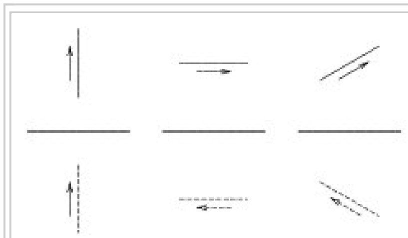
The wave reflected by earth can be considered as emitted by the image antenna.

The net quality of a ground reflection depends on the topography of the surface. When the irregularities of the surface are much smaller than the wavelength, we are in the regime of specular reflection, and the receiver sees both the real antenna and an image of the antenna under the ground due to reflection. But if the ground has irregularities not small compared to the wavelength, reflections will not be coherent but shifted by random phases. With shorter wavelengths (higher frequencies), this is generally the case.

Whenever both the receiving or transmitting antenna are placed at significant heights above the ground (relative to the wavelength), waves specularly reflected by the ground will travel a longer distance than direct waves, inducing a phase shift which can sometimes be significant. When a sky wave is launched by such an antenna, that phase shift is always significant unless the antenna is very close to the ground (compared to the wavelength).

The phase of reflection of electromagnetic waves depends on the polarization of the incident wave. Given the larger refractive index of the ground (typically n=2) compared to air (n=1), the phase of horizontally polarized radiation is reversed upon reflection (a phase shift of π radians or 180°). On the other hand, the vertical component of the wave's electric field is reflected at grazing angles of incidence approximately *in phase*. These phase shifts apply as well to a ground modelled as a good electrical conductor.

This means that a receiving antenna "sees" an image of the antenna but with reversed currents. That current is in the same absolute direction as the actual antenna if the antenna is vertically oriented (and thus vertically polarized) but opposite the actual antenna if the antenna current is horizontal.


The currents in an antenna appear as an image in *opposite* phase when reflected at grazing angles. This causes a phase reversal for waves emitted by a horizontally polarized antenna (left) but not a vertically polarized antenna (center).

The actual antenna which is *transmitting* the original wave then also may *receive* a strong signal from its own image from the ground. This will induce an additional current in the antenna element, changing the current at the feedpoint for a given feedpoint voltage. Thus the antenna's impedance, given by the ratio of feedpoint voltage to current, is altered due to the antenna's proximity to the ground. This can be quite a significant effect when the antenna is within a wavelength or two of the ground. But as the antenna height is increased, the reduced power of the reflected wave (due to the inverse square law) allows the antenna to approach its asymptotic feedpoint impedance given by theory. At lower heights, the effect on the antenna's impedance is *very* sensitive to the exact distance from the ground, as this affects the phase of the reflected wave relative to the currents in the antenna. Changing the antenna's height by a quarter wavelength, then changes the phase of the reflection by 180°, with a completely different effect on the antenna's impedance.

The ground reflection has an important effect on the net far field radiation pattern in the vertical plane, that is, as a function of elevation angle, which is thus different between a vertically and horizontally polarized antenna. Consider an antenna at a height *h* above the ground, transmitting a wave considered at the elevation angle θ. For a vertically polarized transmission the magnitude of the electric field of the electromagnetic wave produced by the direct ray plus the reflected ray is:

$$|E_V| = 2\,|E_0|\,\left|\cos\left(\frac{2\pi h}{\lambda}\sin\theta\right)\right|$$

Thus the *power* received can be as high as 4 times that due to the direct wave alone (such as when θ=0), following the *square* of the cosine. The sign inversion for the reflection of horizontally polarized emission instead results in:

$$|E_H| = 2\,|E_0|\,\left|\sin\left(\frac{2\pi h}{\lambda}\sin\theta\right)\right|$$

where:

- E_0 is the electrical field that would be received by the direct wave if there were no ground.
- θ is the elevation angle of the wave being considered.
- λ is the wavelength.
- h is the height of the antenna (half the distance between the antenna and its image).

Radiation patterns of antennas and their images reflected by the ground. At left the polarization is vertical and there is always a maximum for θ=0. If the polarization is horizontal as at right, there is always a zero for θ=0.

For horizontal propagation between transmitting and receiving antennas situated near the ground reasonably far from each other, the distances traveled by tne direct and reflected rays are nearly the same. There is almost no relative phase shift. If the emission is polarized vertically, the two fields (direct and reflected) add and there is maximum of received signal. If the signal is polarized horizontally, the two signals subtract and the received signal is largely cancelled. The vertical plane radiation patterns are shown in the image at right. With vertical polarization there is always a maximum for θ=0, horizontal propagation (left pattern). For horizontal polarization, there is cancellation at that angle. Note that the above formulae and these plots assume the ground as a perfect conductor. These plots of the radiation pattern correspond to a distance between the antenna and its image of 2.5λ. As the antenna height is increased, the number of lobes increases as well.

The difference in the above factors for the case of θ=0 is the reason that most broadcasting (transmissions intended for the public) uses vertical polarization. For receivers near the ground, horizontally polarized transmissions suffer cancellation. For best reception the receiving antennas for these signals are likewise vertically polarized. In some applications where the receiving antenna must work in any position, as in mobile phones, the base station antennas use mixed polarization, such as linear polarization at an angle (with both vertical and horizontal components) or circular polarization.

On the other hand, classical (analog) television transmissions are usually horizontally polarized, because in urban areas buildings can reflect the electromagnetic waves and create ghost images due to multipath propagation. Using horizontal polarization, ghosting is reduced because the amount of reflection of electromagnetic waves in the *p* polarization (horizontal polarization off the side of a building) is generally less than *s* (vertical, in this case) polarization. Vertically polarized analog television has nevertheless been used in some rural areas. In digital terrestrial television such reflections are less problematic, due to robustness of binary transmissions and error correction.

Mutual impedance and interaction between antennas

Current circulating in one antenna generally induces a voltage across the feedpoint of nearby antennas or antenna elements. The mathematics presented below are useful in analyzing the electrical behaviour of antenna arrays, where the properties of the individual array elements (such as half wave dipoles) are already known. If those elements were widely separated and driven in a certain amplitude and phase, then each would act independently as that element is known to. However, because of the mutual interaction between their electric and magnetic fields due to proximity, the currents in each element are *not* simply a function of the applied voltage (according to its driving point impedance), but depend on the currents in the other nearby elements. Note

that this now is a near field phenomenon which could not be properly accounted for using the Friis transmission equation for instance. This near field effect creates a different set of currents at the antenna terminals resulting in distortions in the far field radiation patterns; however, the distortions may be removed using a simple set of network equations.[36]

The elements' feedpoint currents and voltages can be related to each other using the concept of **mutual impedance** Z_{ji} between every pair of antennas just as the mutual impedance $j\omega M$ describes the voltage induced in one inductor by a current through a nearby coil coupled to it through a mutual inductance *M*. The mutual impedance Z_{21} between two antennas is defined[37] as:

$$Z_{ji} = \frac{v_j}{i_i}$$

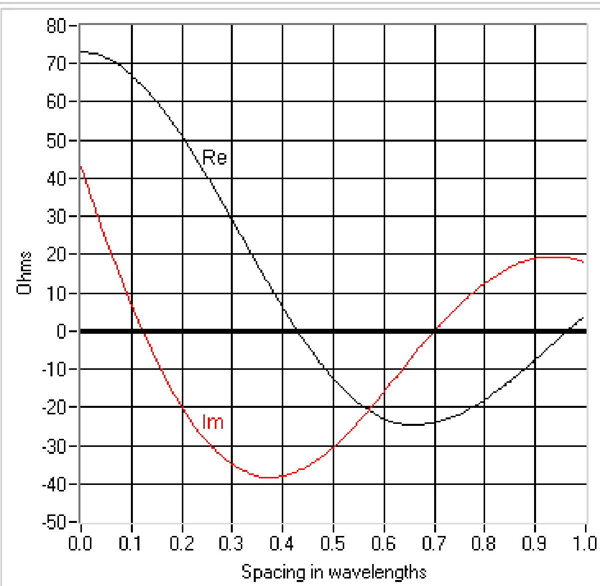
where i_i is the current flowing in antenna *i* and v_j is the voltage induced at the open-circuited feedpoint of antenna *j* due to i_1 when all other currents i_k are zero. The mutual impendances can be viewed as the elements of a symmetric square impedance matrix **Z**. Note that the diagonal elements, $Z_{ii} = \frac{v_i}{i_i}$, are simply the driving point impedances of each element.

Using this definition, the voltages present at the feedpoints of a set of coupled antennas can be expressed as the multiplication of the impedance matrix times the vector of currents. Written out as discrete equations, that means:

$$\begin{array}{ccccccccc} v_1 & = & i_1 Z_{11} & + & i_2 Z_{12} & + & \cdots & + & i_n Z_{1n} \\ v_2 & = & i_1 Z_{21} & + & i_2 Z_{22} & + & \cdots & + & i_n Z_{2n} \\ \vdots & & \vdots & & \vdots & & & & \vdots \\ v_n & = & i_1 Z_{n1} & + & i_2 Z_{n2} & + & \cdots & + & i_n Z_{nn} \end{array}$$

where:

- v_i is the voltage at the terminals of antenna i
- i_i is the current flowing between the terminals of antenna i
- Z_{ii} is the driving point impedance of antenna i
- Z_{ij} is the mutual impedance between antennas i and j.



Mutual impedance between parallel $\frac{\lambda}{2}$ dipoles not staggered. Curves **Re** and **Im** are the resistive and reactive parts of the impedance.

As is the case for mutual inductances,

$$Z_{ij} = Z_{ji}.$$

This is a consequence of Lorentz reciprocity. For an antenna element i not connected to anything (open circuited) one can write $i_i = 0$. But for an element i which is short circuited, a current is generated across that short but no voltage is allowed, so the corresponding $v_i = 0$. This is the case, for instance, with the so-called parasitic elements of a Yagi-Uda antenna where the solid rod can be viewed as a dipole antenna shorted across its feedpoint. Parasitic elements are unpowered elements that absorb and reradiate RF energy according to the induced current calculated using such a system of equations.

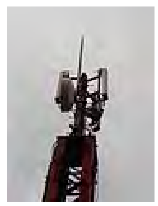
With a particular geometry, it is possible for the mutual impedance between nearby antennas to be zero. This is the case, for instance, between the crossed dipoles used in the turnstile antenna.

Gallery

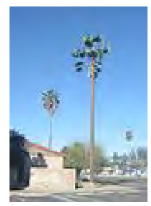
Antennas and supporting structures

A building rooftop supporting numerous dish and sectored mobile telecommunications antennas (Doncaster, Victoria, Australia).

A water tower in Palmerston, Northern Territory with radio broadcasting and communications antennas.

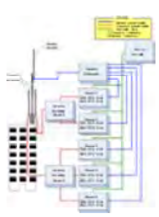


A three-sector telephone site in Mexico City.

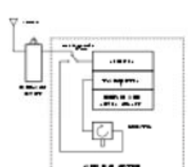


Telephone site concealed as a palm tree.

Diagrams as part of a system



Antennas may be connected through a multiplexing arrangement in some applications like this trunked two-way radio example.



Antenna network for an emergency medical services base station.

See also

- Category:Radio frequency antenna types
- Category:Radio frequency propagation

Wikimedia Commons has media related to ***Antennas***.

- Cellular repeater
- DXing
- Electromagnetism
- Mobile broadband modem
- Numerical Electromagnetics Code
- Radial (radio)
- Radio masts and towers
- RF connector
- Smart antenna
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Categories: Antennas (radio) | Radio electronics

MIJN EERSTE TRANSCEIVER WAS VOOR DE 2 METER BAND

(1977)

Mijn eerste transceiver was voor de 2 meter band en is geschikt voor CW en FM.

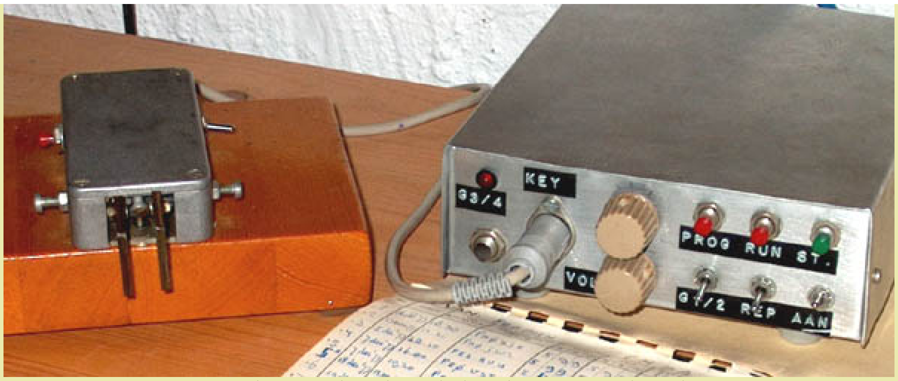
Mijn eerste transceiver was voor de 2 meter band

Toen ik mijn amateur licentie had gekregen, moest er een 2 meter transceiver worden gebouwd. Het schema stond in Electron. Helaas weet ik niet meer wie de ontwerper was, ik vermoed dat het Klaas, PA0KSB was. Aangemoedigd door een zendamateur werd besloten dit ingewikkelde apparaat te gaan bouwen. Maar alvorens de transceiver te bouwen, werd het ontwerp aangepast omdat ik ook graag CW wilde hebben. En zo werden er nog diverse onderdelen gewijzigd, zoals het gebruik van kristallen voor de local oscillator van de 2e ontvanger mengtrap. En een frequentie kalibrator om exact op het juiste kanaal af te stemmen en nog een schakelaar om je eigen modulatie te monitoren.

De eenvoudige 2 meter antenne waarmee verbindingen door heel Europa werden gemaakt.

Geen eenvoudig apparaat

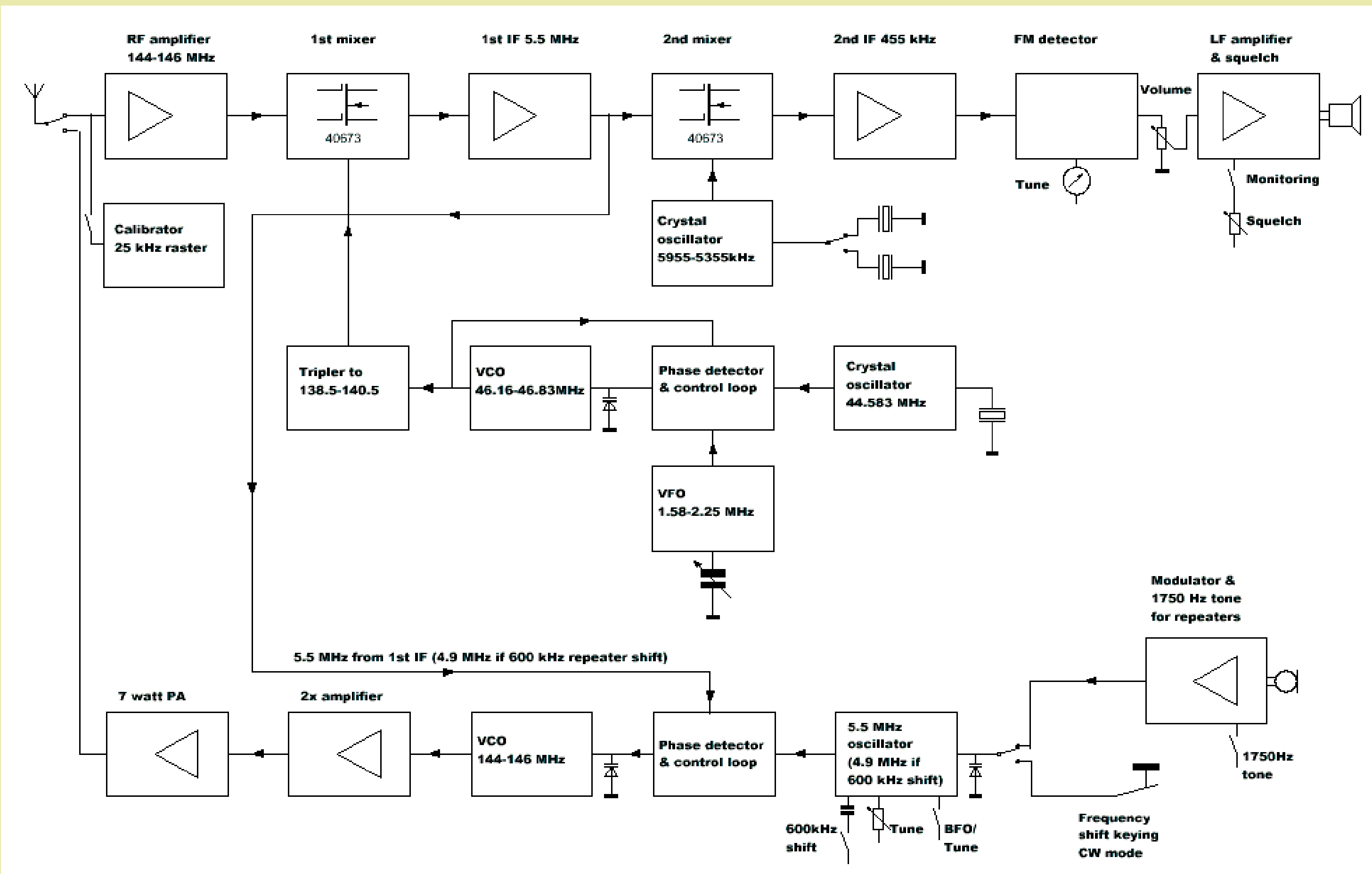
Dit was zeker geen Barefoot Technology project. Ik had nog nooit een ingewikkeld apparaat gebouwd en wist niet wat me te wachten stond. De verwachting was dat alles zou werken nadat het in elkaar gesoldeerd was, maar dat was natuurlijk niet zo. Er zijn heel wat dingen aangepast en fouten die ik gemaakt had gecorrigeerd... Uiteindelijk werkte de transceiver naar behoren. Er zijn heel veel QSO's mee gemaakt, met FM maar vooral CW QSO's. Deze transceiver is wel het moeilijkste dat ik ooit gebouwd heb.



De Junker seinsleutel werd al snel vervangen door deze squeeze-memory keyer. Dat was een enorme verbetering. Links seinen en rechts schrijven en de set bedienen, dat ging uitstekend!

Het ontwerp

Het ontwerp is gebaseerd op de mogelijkheden uit die tijd. Nu zouden we het heel anders doen. Bouw deze transceiver dus niet na, het artikel is bedoeld om een uitleg te geven over de vele leuke ideeen die in de transceiver verwerkt zijn en wat voor soort schakelingen men toen gebruikte.



Blokschema.

Ontvanger.

Het LO signaal van de 1e mixer van de ontvanger wordt verkregen door een VCO te laten locken op de frequenties van een kristal oscillator van 44.583 MHz en een VFO met een frequentie bereik van 1.58 MHz to 2.25 MHz. De VCO frequentie varieert dan tussen 46.16 en 46.83 MHz. Door een tripler wordt deze 3x vermenigvuldigd naar 138.5-140.5 MHz.
De 1e MF frequentie is 5.5 MHz, de tweede 455 kHz. De FM detector is voorzien van een afstemmeter. Wanneer de naald in het midden staat, heb je de ontvanger precies afgestemd op de frequentie van het tegenstation. Ook kun je de frequentie kalibrator gebruiken om precies op het 25 kHz kanaal af te stemmen. Er is een monitor schakelaar om je eigen uitzending/modulatie te beluisteren tijdens het zenden.
De afstemmeter wordt ook gebruikt om de 5.5 MHz oscillator van de zender exact op de goede frequentie af te regelen. Voor het werken over repeaters moet dit 4.9 MHz zijn (600 kHz lager). Daarom is er een tweede kristal van 5355 kHz, dat ingeschakeld wordt bij het zenden met een shift van 600 kHz.

Zender.

Het signaal van de VCO wordt versterkt tot een uitgangsvermogen van ongeveer 7 watt. De ontvanger zal dit zendsignaal ontvangen via bijvoorbeeld de kleine capaciteiten in het antenne relais. Het 5.5 MHz MF signaal van de ontvanger wordt in een fase detector vergeleken met een 5.5 MHz vrijlopende oscillator. Een regellus regelt de VCO bij zodat de zendfrequentie gelijk is aan de ontvangstfrequentie. De vrijlopende 5.5 MHz oscillator is natuurlijk

niet superstabiel. Daarom moet hij voor het begin van een uitzending bijgeregeld worden. Dit gebeurt door deze 5.5 MHz oscillator aan te zetten en af te regelen met de tune potentiometer en de afstemmeter van de ontvanger. Dit 5.5 MHz signaal straalt voldoende in op de 1e MF en kan zelfs als BFO worden gebruikt voor het ontvangen van CW. Maar ik gebruikte altijd een kortegolf ontvanger aangesloten op de 1e MF van 5.5 MHz voor CW ontvangst. Voor het werken via repeaters moet de frequentie van de vrijlopende oscillator 600 kHz lager zijn, oftewel 4.9 MHz. Daarom zit er in de ontvanger ook een kristal van 5355 kHz, zodat de 1e MF dan even 4.9 MHz wordt voor de afregeling.
De vrijlopende 5.5 MHz oscillator wordt FM gemoduleerd voor spraak en voor CW wordt Frequency Shift Keying toegepast. Aan/uit modulatie voor CW is niet mogelijk, dan zou de VCO bij ieder teken steeds opnieuw moeten locken en dat gaat veel te traag. Het locken duurt langer dan de lengte van een punt of streep.

Wanneer je een gedetailleerde uitleg van het schema wilt lezen, klik dan op de onderstaande link:

Klik hier voor een gedetailleerde uitleg van het schema

Afregeling
De afregeling moest met heel eenvoudige middelen worden uitgevoerd. De meest gebruikte middelen waren een universeel meter en een dipmeter van Heathkit, die speciaal voor dit project werd aangeschaft. De frequentie kalibrator werd geijkt op de frequentie van een repeater station. En heel veel gebeurde op het gehoor. Gelukkig waren daarvoor vele langdurige QSO's te ontvangen.

De dipmeter van Heathkit was een goede investering. Hij is heel veel gebruikt bij dit- en allerlei andere knutselprojecten.

Resultaten
De transceiver is heel veel gebruikt, natuurlijk voor QSO's in FM maar vooral voor CW verbindingen. De twee meter band is een heel interessante band door de vele soorten van condities. Het enige wat ik ooit als nadeel heb ervaren was de matige nevenkanaal selectiviteit. Wanneer er twee locale stations op 145.525 MHz zaten, hoorde ik ze ook zwak wanneer de set op de aanroep frequentie van 145.500 MHz stond afgestemd.
Voor CW werd een achterzet ontvanger toegepast, de SSR1. Deze was verbonden met de 5.5 MHz middenfrequent en daarop afgestemd. Zo kon ook AM worden ontvangen. Er is op die manier een QSO gemaakt met een Engelse amateur die nog in AM werkte. De zender deed het prima, harmonischen onderdrukking was meer dan 60 dB. Daarvoor zijn twee jaar na de bouw nog wat extra laagdoorlaatfilters aangebracht. Van het oorspronkelijke ontwerp is de onderdrukking van de harmonischen te laag.
Voor het zenden in CW was er een memory keyer. Later kwam er nog een 40 watt eindtrap. Ook zijn er RTTY verbindingen gemaakt, eerst met een oude mechanische telex maar later met een destijds moderne, hele dure computer, de Acorn Atom. CPU speed 1 MHz en 32k geheugen... De monitor was een zwart-wit TV.

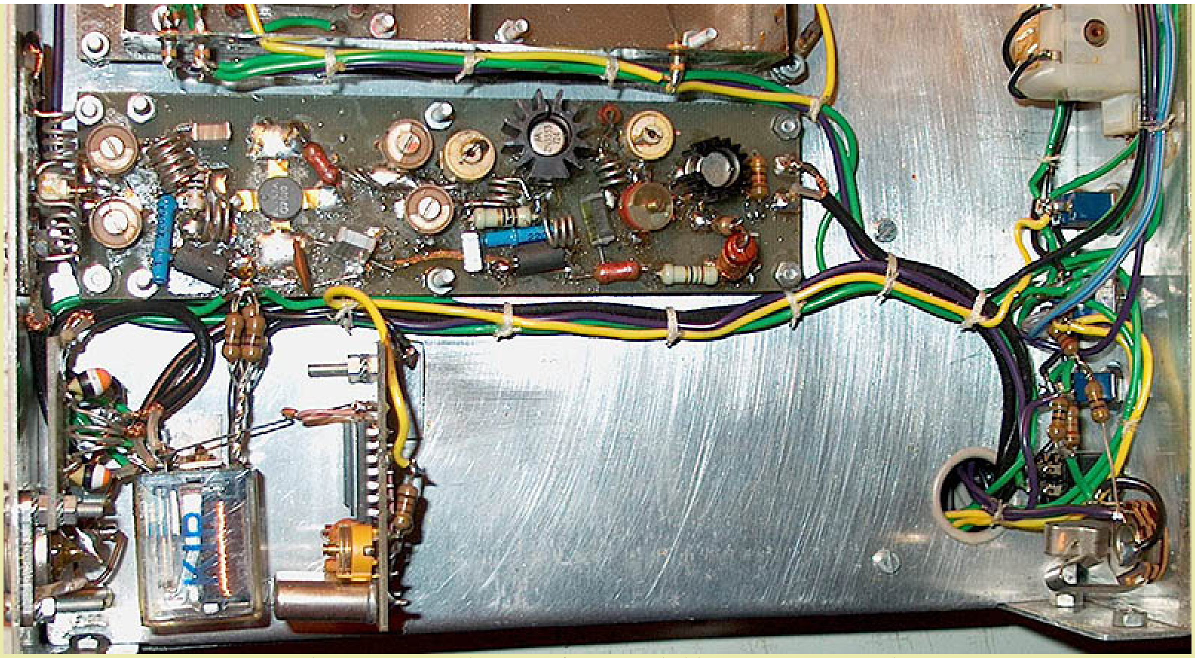
RTTY met de Acorn Atom computer uit de tijd dat men nog op blote voeten liep... CPU speed 1 MHz en 32k memory!

Meetresultaten van de ontvanger
Maar nu, 30 jaar later, was ik toch wel benieuwd naar de kwaliteit van de ontvanger, die behalve de nevenkanaal selectiviteit, altijd prima beviel. Ik kon wat metingen doen volgens de ETSI standaard EN300 086. Deze is bedoeld voor mobilofoons en kan iedereen vrij downloaden van de ETSI website (na registratie d.m.v. het invullen van je e-mail adres). Hieronder de resultaten:

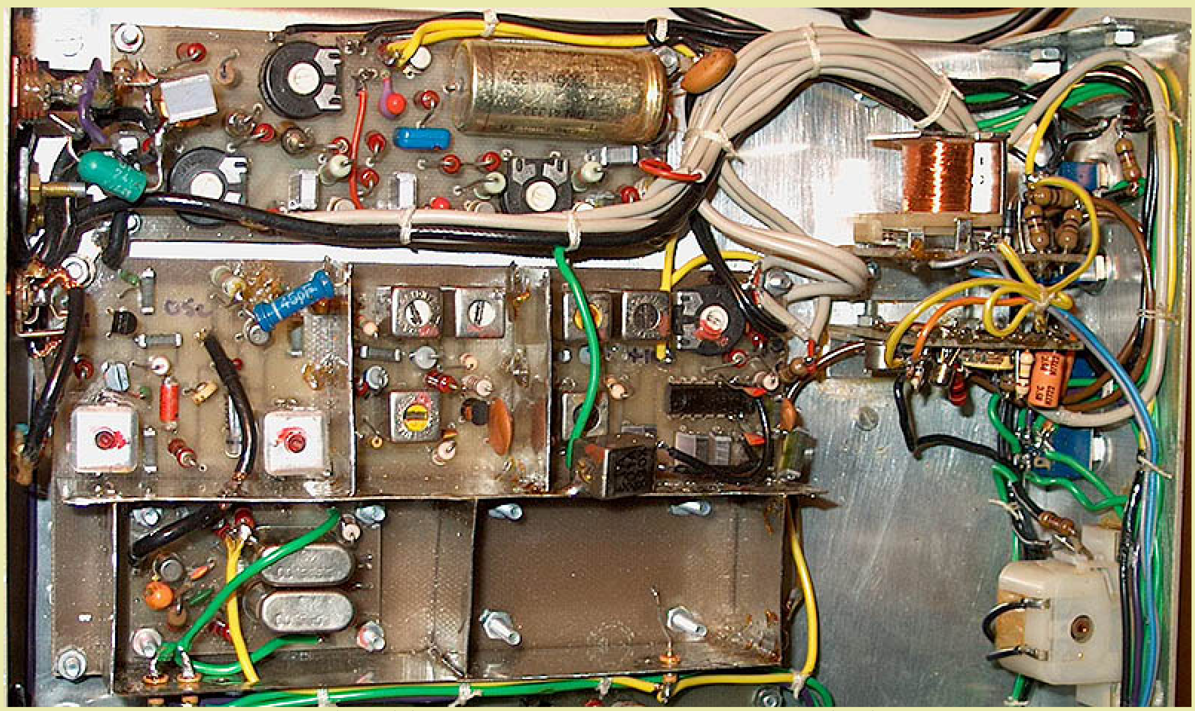
Test	Meetwaarde	Limiet	Opmerkingen
Sensitivity	-2.8 dBuV emf	+6 dBuV emf	Goed!
Co-channel rejection	-4.2 dBc	0-8 dBc	Goed!
Blocking and Desensitization @ -1 MHz	93.3 dBc	84 dBc	Goed!
Intermodulation response @ 50/100 kHz	47.5 dBc	70 dBc	Slecht.
Adjacent channel selectivity	ch-25kHz: 32.6 dBc ch+25kHz: 41.7 dBc	70 dBc	Erg slecht...
Spurious response spiegelfrequentie IF1	11.0 dBc	70 dBc	Slechter kan het niet!!!
Spurious response spiegelfrequentie IF2	82.1 dBc	70 dBc	Goed!

Dat de adjacent channel selectivity niet zo goed was, heb ik wel eens gemerkt. Soms waren er geluiden te horen van locale amateurs op naastliggende kanalen. Maar dat de onderdrukking van de spiegelfrequentie van de eerste MF van 5.5 MHz zo vreselijk slecht was, dat heb ik nooit gemerkt en had ik ook niet verwacht. Dat moet met 4 HF kringen veel beter kunnen, is dus heel slecht afgeregeld.

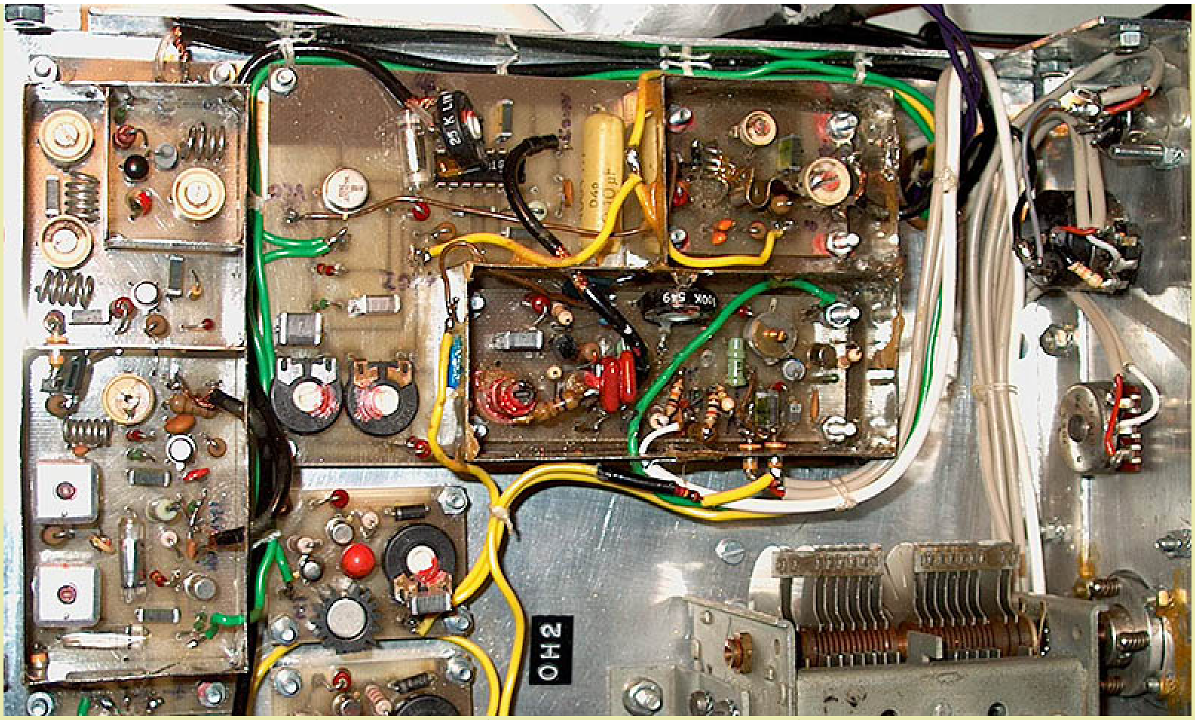
FOTO'S VAN DE CONSTRUCTIE



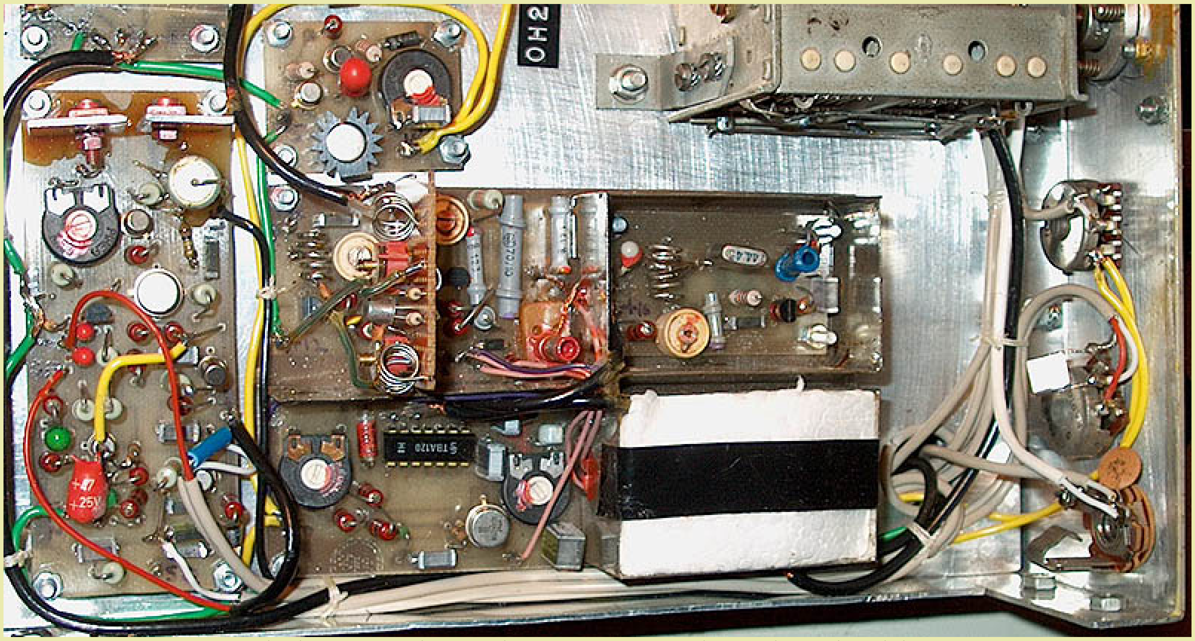
Zender stuur- en eindtrappen, frequentie kalibrator en antenne relais.
Tegen de achterkant zitten 2 extra low-pass filters voor de harmonischen onderdrukking.



Bovenaan de modulator en 1750Hz repeater toongenerator, rechts de CW vox.
In het midden de 1e MF van 5.5 MHz en de 2e MF van 455 kHz met FM detector.
Links onder de local oscillator van de 2e mixer met de kristallen 5955kHz en 5355kHz.



Links de HF trap en de 1e MF trap van 5.5 MHz van de ontvanger.
Boven de zend VCO (met koelvin), PLL en 5.5 MHz oscillator (rechts-midden).
Onder een van de twee gestabiliseerde voedingen van 9 volt.



Links de LF versterker van de ontvanger. Boven de tweede 9 volt stabilisator.
In het midden de VCO van de ontvanger met de VFO onder het witte piepschuim.
Leuk detail: de metalen ronde uitvoering van de uA741 op-amp (midden onder).

BACK TO INDEX PA2OHH

Turquoise Energy Ltd. Catalogue

To order from this catalog, please send e-mail to:

Craig	Carmichael
craig	@saers.com

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Latest Revision: October 20th 2011

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1. Motor Kits

Electric Hubcap Motor Kit*: $499

(Electric Weel motor kits are not yet available.)

*The required epoxy resin and supermagnets are not included in the motor kit. Supermagnets can be ordered on line from a number of sources. Epoxy resin is commonly available.

A "complete" kit (epoxy and supermagnets not included), and all the special parts individually, are available below to make building them as simple as:

* epoxy the supermagnets onto the rotor
* wire up the coils (soldering recommended)
* assemble it (adjust shaft spacers).

The parts of the Electric Hubcap motor kit
(The black body parts shown, of sturdy polpropylene-epoxy, come predrilled and painted with heat resistant polyurethane. Coils come unwired.)

CAUTION: These motors are designed to run up to 2000 RPM. They can attain a dangerously high RPM with the risk of violent failure. Until this is rectified by a future microprocessor-based motor controller, 36 volts is the maximum supply voltage, and RPM should be carefully monitored.

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2. Electric Hubcap, Electric Weel Motor Parts

Brief Specs/Description: 36 volts - 130 amps - 5 KW - axial flux - 0-2000 RPM - shortest (circular) wire winding lengths - high efficiency toroidal iron powder coil cores - BLDC with FeNdB ("NIB") supermagnets - Large flux gap and reinforced magnet coatings prevent magnet degredation over time - Pancake shape 11.5" x 4.5" - 30 pounds

This type of motor has several names describing it electrically, each of which is applicable but not necessarily complete or appropriate. First, it's a 3-phase synchronous motor (traditional name) or permanent magnet synchronous motor (PMSM).
Of course, it is run from DC power via a motor controller that switches the DC on the fly into three phase AC power, "synchronized" only with itself. A permanent magnet "DC" motor does the same mechanically via the brushes on its commutator, so another way of looking at it is that it's a "DC" motor with the controller replacing the brushes. It's best known today as a brushless DC motor or "BLDC".
It's a simple design wherein there are no electrical connections to the moving rotor with its permanent magnets. Instead of switch/brush connections in the motor, three magnet sensors (one per phase spaced 120º apart [electrically]) tell the motor controller where the N and S magnets are in their rotation, indicating which coils to activate with which polarity. In the Electric Hubcap the coils are wound with heavy wire around super high efficiency iron powder cores. (The RPM and switching frequencies are low enough that fine wire would be superfluous.)

Please see the *Electric Hubcap Motor Building Manual* for more detailed motor & motor operation description.

The Electric Hubcap Motor consists of the following major parts/assemblies:

1) **Case Parts:**

The case consists of four parts molded from polypropylene-epoxy composite. This tough, usually overlooked composite is stronger and lighter than fibreglass-epoxy. (Hint: Polypropylene fabric is sold as "landscaping fabric".) Metal parts would cause magnetic drag that would spoil efficiency.

* **Stator outer plate**
  - molded polypropylene-epoxy ring, 11.25" diameter.
  - 9 molded "buttons" hold the coils in place.
  - Steel bearing holder "washers" mount to hold bearing centered in 3" center hole.
* **Center Plate & Rotor Outer Cover** (molded together)
  - 4" center hole for ventilation air, clearance
  - ring 11.25" diameter with "buttons" to align coils.
    (The two coil mounting plates are the "bread" of the sandwich. The coils are the "filling")
  - Magnet rotor side has channel where magnets sweep around close to stator coils, but the rotor compartment is separated from the stator compartment.
  - Thick outer shell (11.5" O.D.), molded to the center plate, protects people in the area in the event of magnets breaking off the rotor. (usually from over-revving motor - possibly from poor construction)
* **Rotor End Cover**
  - Holds rotor end bearing assembly centered
  - Ventilation air exit holes

2) **Stator Parts:**

* **9 electromagnet coils** with low-loss toroidal iron powder cores, wired to heavy 3-pin plug
* **Magnet position sensor board** wired to 5-pin trailer lights plug
* **motor temperature sensor** (AD590 or LM335, 10mV/ºK)

3**) Moving Parts**

* **1" diameter round shaft** (or custom shaft)
* with common **1" trailer wheel bearings**, **bearing spacers** on shaft
* **SDS or SD 1" taper lock shaft bushing with shaft key** (holds magnet rotor, spaces bearings)
* **Flat Plate Rotor disk**, sintered zinc primed and polyurethane finished (similar to 'powder coating') for maximum corrosion resistance & magnet adhesion
* rotor has **12 supermagnets, 2" x 1" x .5"** (epoxied on; epoxied polypropylene strapping magnet protection/reinforcement)

***** Case parts molds have recently been improved for sturdiness and safety - new pictures coming soon. *****

Basic motor layout.
L to R: shaft, rotor compartment, stator compartment.

Stator Parts (Electric Hubcap & Electric Weel motors)

(All motors) Stator Coils: prewound with 21 turns of #11 wire, iron powder cores, coated with paramagnetic ilmenite in sodium silicate - $10 each. Very low losses, 70ºC rated.

Three coils in series per phase gives 63 total turns for 36 volts (nominal) operation.

(All motors) Magnet & Temperature Sensor Assembly - $35

Three magnet sensors and temperature sensor on PCB, with plugs and wires, complete & ready to bolt onto the upper stator ring and plug into the motor controller.

Rotor Parts (Electric Hubcap motor)

Magnet rotor disk zinc anti-corrosion primed, urethane finish - $50
SDS or SD **Taper Lock Shaft Bushing** to mount rotor on 1" shaft - $30 (Hint: these are locally available most places for about $20. Other shaft sizes are available in 1/16" increments to 2".)
1" HTSR #4140 machine shaft

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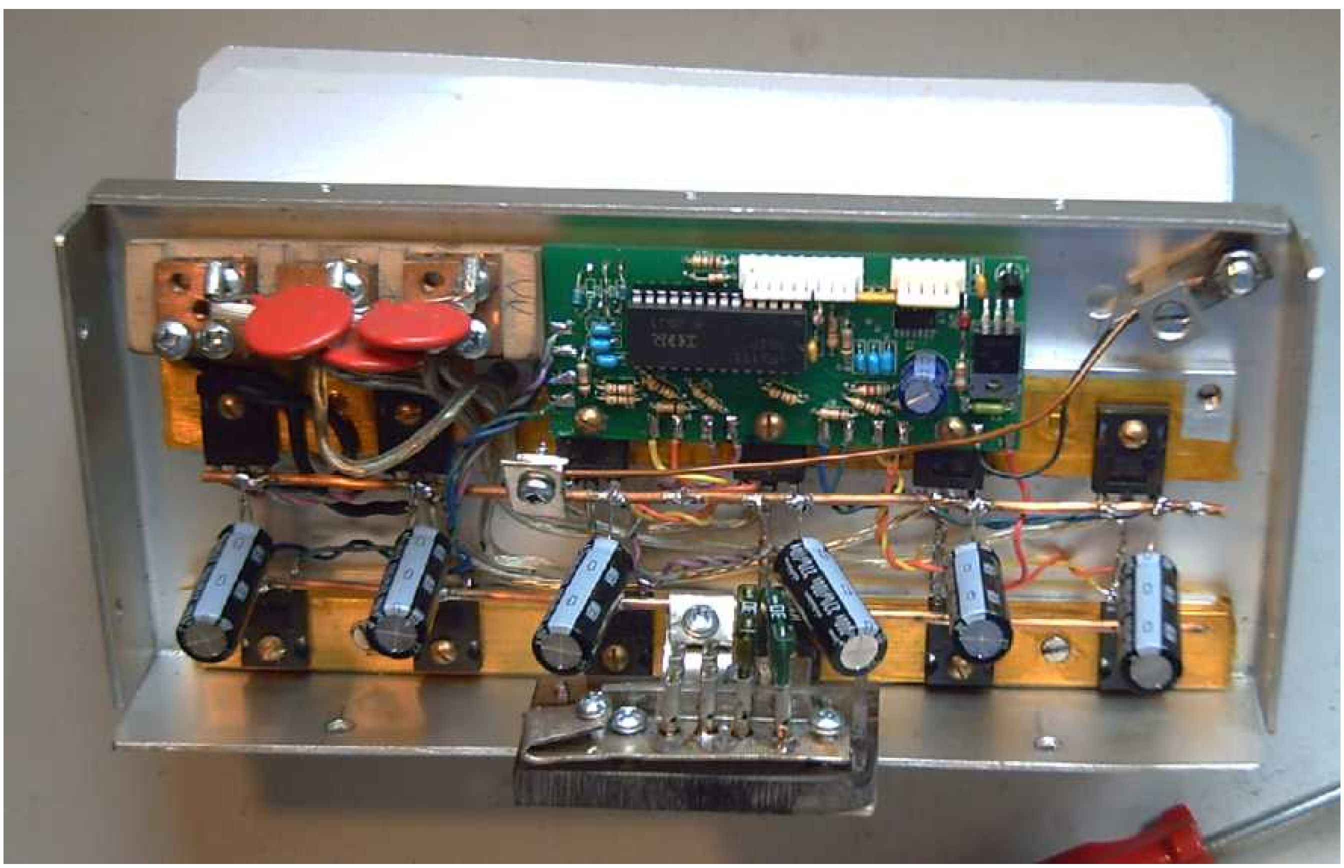
3. Turquoise Brushless Motor Controllers - 5KW BLDC Motor Controllers for Electric Hubcap, Electric Weel Motors



Controller plate without chassis
(Heat sink fins are visible behind)

Superior BLDC motor controller based on IR2133 controller/MOS gate driver chip. Specs in Brief:
- Complete unit ready to install with chassis, breaker, terminal blocks...
- Simple controls: minimally, speed control potentiometer and Fwd-Off-Rev switch.
- Hard-wired unit: no microcontroller
- 3 phase control, 6 pin header - motor sensors control, 10 pin header - operator controls and readouts
- 60 V (components abs. max. limit) 42 V (nominal max) 36 V (typical)
- 150 A (limit for larger currents depends on durations, fuse & breaker ratings) 130 A nominal
- Modulation: Current Ramp Modulation ("CRM"), a form of direct torque control
- Cooling: high efficiency for low heat generation, aluminum fins, aluminum chassis, passive. Made to absorb transient heavy loads without rapid component heating

Please see *Turquoise Motor Controller Building Manual* for detailed description. Microcontroller overcontrol unit TBA.

The controller consists of the following major parts/assemblies:

1) **Motor Controller Plate**. This aluminum plate forms one side of the chassis. It can be unscrewed for servicing or replacement without disturbing the remainder of the chassis. It holds:
   * The 2 inner and 2 outer aluminum heatsink bars
   * the heatsink fins (clamped under the outer heatsink bars - aluminum roofing flashing)
   * the 12 power mosfet transistors that drive the motor coils, on the inner heatsink bars.
   * The 'logic' circuit board (connects to operator controls, magnet sensors, mosfets).
     (It bolts onto three of the mosfets.)
   * the heavy wiring terminal blocks & fuses holder assy

2) **The Wiring Box/Chassis** (the other five sides of the box). In the box:
   * Circuit Breaker - 40+ VDC, 150 Amps.
   * 'Solenoid' (12 volt contactor relay) to turn system on with car key (car systems)
   * Cable clamps, glands

Turquoise Motor Controller (includes chassis, et al), Assembled and Tested - $450

Kit with all parts (you solder & assemble. Includes chassis, et al) - $260

Motor Controller Aluminum Mounting Plate with Heatsink Bars - $30

This is the mounting unit and heatsink base for the motor controller itself, exclusive of the wiring box.

Motor Controller 'Logic' Circuit Board with parts (you solder) - $50

The circuit board is the low-power circuitry that connects to everything and tells the high power stuff what to do. With International Rectifier IR2133 5KW brushless 3-phase MOS driver/motor controller chip.

Above plus 12 IR3260 MOSFETs (rated 60V 120A), 6 - 270uF/100V line filter capacitors,

Aluminum Chassis Box 6" x 9.5" - $45

Larger size wiring box for where space isn't an issue. Does NOT include motor controller mounting plate side.

Aluminum Chassis Box 4" x 9.5" - $45

Smaller size wiring box for tighter spaces (eg, in cars). Does NOT include motor controller mounting plate side.

Custom sizes - please enquire.

NiMH Stackable 12 Volt Battery Cases & Handy Battery Sticks

1. **NiMH Stackable 12 Volt D Cell Battery cases** - $25 (*requires ten D cell batteries*)
2. **26", 12 volt handy battery stick** - $90. (12 volts, 10 AH, 30A, 70 CA - 10 NiMH D cells)
3. **14", 6 volt handy battery stick** - $45. (6 volts, 10 AH, 30A - 5 NiMH D cells)
4. **7" x 5, Quintos Battery Stick** - $95 (12V, 10 AH, 30A, 70 CA - 5 short pipes of 2 NiMH D cells) - While quantities last.

[images below]

Nickel-metal hydride batteries are exceptionally long life batteries capable of handling high currents in both directions. After their rated 1000 charge-discharge cycles, they're simply down to 80% of their rated capacity. If lead-acid car batteries were rated the same way, they'd be rated for a only few tens of cycles at best. And they're about 60% the weight of lead-acid, and they're green - not environmetally toxic waste even if dumped. Laptop computer users report NiMH batteries also last longer than lithium ion types.

NiMH batteries (flooded cells) made GM's EV-1 and other electric cars famous in the documentary movie *Who Killed the Electric Car?*. 15 years later, a Toyota RAV-4 EV (one of a handful that wasn't crushed) was reported to be losing considerable driving range.

After the cars were crushed, Chevron oil company via its proxy company Cobasys stopped production just before they would likely have hit the box stores to replace lead-acid, and has been permitted to acquire over 100 patents for metal hydrides (see Cobasys on Wikipedia) to prevent anyone, anywhere US "technology death by patent" is "honored", from manufacturing (or importing) this excellent low-cost battery chemistry in sizes much larger than "D" cells. Even the D cells aren't available locally in stores here, tho AA cells are available in D size packages at inflated prices.

As one result, everybody started developing lithium batteries, which are intrinsically much more costly and only somewhat lighter in weight. As another result, NiMH dry cells have become ever better, amazing for their size, and the D cells, tho much more costly than the Chevron-banned big liquid filled cells would be, are maintenance free and are commonly used in x100's quantity to make hybrid car batteries. But they're tiny for automotive, RV, boat, solar and other large battery needs.

So is there some practical way to build up big batteries up from small dry cells? The hybrid car makers have done it one way for inside hybrid batteries, but it's not mechanically solid for external use. Turquoise Energy has two answers: First, **stackable 12 volt NiMH battery cases**, and second, **Handy Battery Sticks**! 1-1/4" lighter wall PVC irrigation pipes are filled with NiMH D cells to make 6 or 12 volt batteries, and ends are glued on. They have 1/4" bolts on each end for connecting to the load, or to more battery sticks to assemble large batteries for automotive, solar/wind storage, or other uses.

Stackable cases type

Single NiMH 12V D cell cases - 25 $ each.
L: Newset version
R: First version (obsolete)

12V & 6V Handy Battery Sticks (10 D cells & 5 D cells): 85$, 45$ batteries included.
Empty tubes with ends: 10$, 8$. Second end needs to be glued or screwed on after filling.
(Transition plumbing pipe glue or methylene chloride. Screw pilot holes are not provided.)

Quintos Battery Sticks - 12V in 5 pipes of two cells each for smaller spaces. (90 $ each while quantities last)

With over 70 cranking amps to -10ºc, three banks of 12V sticks can replace
lead acid car batteries and will probably last 15-25 years.
The 13.8 volts standard car charging system voltage (about 13.8 to 13.95 volts) is (by chance)
ideal voltage for constant voltage NiMH float charging (of 10 cells in series, 12 V).
These six 6V sticks (configured as 3 parallel banks of 12V) have been in this car for over two
years now and still working like new in spite of considerable abuse.
Now this would be made with a 3-stack of the new battery cases.

LED Lighting Products

Turquoise Energy (TE) integrated LED lighting fixtures and table lamps are conceived on the principle that

building a 120 VAC to low voltage DC power supply into individual low-voltage, low power 'bulbs' is intrinsically a poor way to make LED lights. Instead, since they use little power, a low voltage DC integrated lighting fixture of any desired brightness is conveniently plugged into a separate, commonly available power adapter (included).

An integrated diffuser prevents the sharp point-source glare so common in LED lighting. Altho LED emitters have various colour designations, the light is also conditioned by the diffuser. For example, a yellowish lamp shade will make the light look yellowish. I generally describe the light simply as "very white". Even "cool white" LED emitters have a broader spectral distribution than "cool white" fluorescent lights. I wasn't sure I would like it, but I found it pleasant and after a couple of weeks, I was used to it and didn't notice the colour at all. (But stay tuned to
Turquoise Energy News for future LED color lighting experiments!)

Here are seven commonly cited reasons LED lighting hasn't taken over the market, none of which apply to Turquoise Energy LED lighting except the first:

1. It costs a lot. This is true, but it will pay for itself in as little as a year in reduced costs, depending on electricity rates and usage. At 10 cents per kilowatt hour, a 100 watt bulb uses 88$ of electricity if left **on** full time for one year, exclusive of replacement bulbs cost. Electricity for a TE 12 watt LED light costs 12.50$, and the light should last 6-12 years of **on** time (50000-100000 hours), saving around 450-900$ of electricity (and 25-100 lightbulbs) over its lifetime. Where rates are higher, savings are greater. Savings over fluorescent bulbs and tubes are also substantial.

2. Available LED 'bulbs' aren't bright enough for common lighting needs. For brightness comparison, a typical 60 watt tungsten (incandescent) bulb is 800-900 lumens, and 100 W is 1500-1700. Most LED bulbs are 450 lumens or less. TE LED light fixtures are available in brightnesses to replace up to about 150 watt bulbs. The fixtures will seem somewhat brighter than the same lumens figure in a tungsten bulb because they shine more in the desired direction (eg, downwards to horizontal rather than up at the ceilng) rather than equally in all directions, and because of the whiteness of the color.

3. LED lights normally gradually dim rather than fail, but some become noticably dull dissapointingly soon. This is mostly from running them at too high a power and too hot. The cooler LEDs run, the longer their life and retention of maximum brightness, and at all times LED emitters run brightest when running cool. TE lights' external power supply, efficient LEDs run at 1/3 of full power, robust heatsinks and ventilation holes, ensure cool running LED lights, which stay brightest longest as well as using minimum energy. Under these conditions, according to LED manufacturers projection graphs, they're likely to be lit for 100,000 hours (over 11 years - if never turned off) or more before they're down to 70% brightness. (Of course, more emitters are required to attain the desired brightness. This doesn't help the initial cost, but it reduces the long term cost.)

4. It has also been said that the bulbs often prematurely fail entirely. Evidently this is failure of the 120 VAC to DC power supply rather than the LED emitter(s). TE LED lights avoid this possibility by using external power adapters. Even in the event of failure, these are widely available at low cost.

5. They are too "sharp" - intense or glaring. The tiny pinpoints of bright light leave spots in front of the eyes. Turquoise Energy fixtures incorporate good frosted diffusers to even the light into a nice glow. (The "plastic jar" diffuser lamps should be fitted with a good lampshade.)

6. The bulbs flicker, giving a strobe effect. This is the result of insufficient or missing filter capacitors, which is in turn because there isn't room for a proper power supply inside a light bulb. Having modern switching power adapters, or using battery power, TE lights are completely steady.

7. Someone said they'd heard LED lighting gives off UV light. LED makers say only UV LEDs emit any UV at all, but that the intense blue point source light of blue and white emitters can be harmful to the eyes. TE light fixture diffusers spread this light and render it harmless. (Looking at a bare filament in a 100 watt clear tungsten bulb is probably harmful too.)

1. LED ceiling or wall fixtures, with power adapter

6" Globe Fixtures: approx. 6" diameter, 7" tall

Low Profile Mushroom Fixture: approx. 7.5" diameter, 4" height

Large Mushroom Fixture: approx. diameter 8", height 7"

LED Light Fixture Price Chart. Power adapter is included. All fixtures are white frosted glass or plastic.

Watts and lumens figures are approximate and vary with temperature: the lights start cold a little under power and brightness, increasing approximately to near spec. in around 10 minutes. Lumens figures are based on manufacturer's (Cree) or dealer's (other types) data and general known LED emitter characteristics. Watts are for given supply voltage and are for the light only: they do not include power used internally by the power adapter. (Add about 15%-20% for typical regulated voltage power adapters a CSA/UL approved adapter is included.) All fixtures have an internal fuse (mostly to protect them against higher voltage supplies).

CAUTION: *DO NOT TURN ON THE LIGHT WITHOUT THE DIFFUSER COVERING IT.* Eye damage can result from looking at the bare emitters because the light is so intense. It's like looking at the sun. (Or as one person put it, "They're like little welding arcs!")

Lumens/ Watts/ Emitter	6" Glass Globe $	6" Acrylic Globe $	6" Glass Mushroom $	7.5" Low Profile Glass Dome Mushroom $	8" Large Mushroom $	
1. 700 / 6 / 2x Cree XM-L, T6 cool white (6v)	80	90	90	100	95	
2. 900 / 10 / 2x 450 lumen, 12v automotive twist socket bulbs	95	105	105	115	110	
3. 1050 / 9 / 3x Cree XM-L, T6 cool white (9v)	90	100	100	110	105	
4. 1100 / 14 / 2x generic emitter (12v)	90	100	100	110	105	
5. 1400 / 12 / 4x Cree XM-L, T6 cool white (12v)	105	115	115	125	120	
6. 1650 / 21 / 3x generic emitter (12v)	105	115	115	125	120	
7. 1800 / 20 / 4x450 lumen, 12v automotive twist socket bulbs				135	130	

LED Light Fixture model number is: LEDLF[line number as shown][globe type]
Globe types: GG6, AG6, GM6, GD7, GM8 - for Glass Globe 6", Acrylic Globe 6", etc. per table

So, for the 1050 lumen, 9 volt unit in a 6" glass globe, model number is: LEDLF3GG6

Quantity	1	2-3	4-7	8-15	16+	
Discount	0%	5%	8%	10%	12%	
BC Hydro Rebate	TBA	TBA	TBA	TBA	TBA	

Prices are subject to change without notice.

This fixture is simply screwed to the ceiling, eg, near the old fixture. It has a power adapter socket on the side. The power adapter (included) can be plugged into the original fixture using a screw-in receptacle, in which case the original light switch is employed. Since the LED emitters point down to horizontal and throw less light at the ceiling, a 1400 lumen unit is at least equvalent to a 100 watt incandescent bulb (1500-1700 lumens). Power is about 12 watts for the light itself, and the power adapter uses about 3 more, total 15 watts. (Can also be powered from 12 volt batteries, such as our **Handy Battery Sticks.**) For optimum long-term performance, mount base up (ie, ceiling) to horizontal (ie, wall).

Table Lamps

3" PVC "art deco" plumbing pipe table lamps are also available. With 6" diffusers, add $10 to above prices (first three columns only). With plastic jar diffuser, add $5 to first column. With plastic jar, a lampshade (not included) *must* be used to further diffuse the bright points of light. Glass diffusers can't be drilled for ventilation or to hold a lampshade, and will run hotter than the other lights. Optional with the plastic globe.

Table lamps have a "bright-off-dim" switch near the bottom of the lamp.

100 Watt incandescent lamp (left) and 9 watt, LED 1000 lumen PVC pipe lamp (right).
The aimed LED emitters throw more light forward and less back towards the wall.

Notes on LED emitters

Efficiency: No emitter is 100% efficient -- all make some heat along with their light, tho much less than other types of lights. (A rough calculation says 100% efficiency might be around 140 lumens/watt.) The ones emitting over 100 lumens of light per watt thus make considerably less heat than those of 50 lumens per watt or less. Choices of emitters bright enough for everyday lighting are so far somewhat limited. The most efficient types tend to cost most, and the electricity savings are great with any good type. Choose the most efficient in particular if they're to be run off batteries or where power is especially limited. Limiting heat production is of little or no concern for building lighting -- unlike with any other type of light. On the power grid, even 10 extra watts generally costs under a dollar a month (eg, 60-90¢ @ 7-10 ¢/KWH) -- and that's if the light is always on.

Rating: Those checking out specs will note that the emitters used are rated for much higher power and lumens than these lights are putting out. That's because the maximum rating and the best use are two different things. The Cree XM-L emitters, for example, are rated 10 watts, 1000 lumens and are being used at 3 watts, around 375 lumens. They are more efficient at lower power and they run cooler. If used at full power the lifespan is much shorter. To attain 25000 to 50000 hours of life as well as highest efficiency, they are generally used at around 1/3 of their rated current.

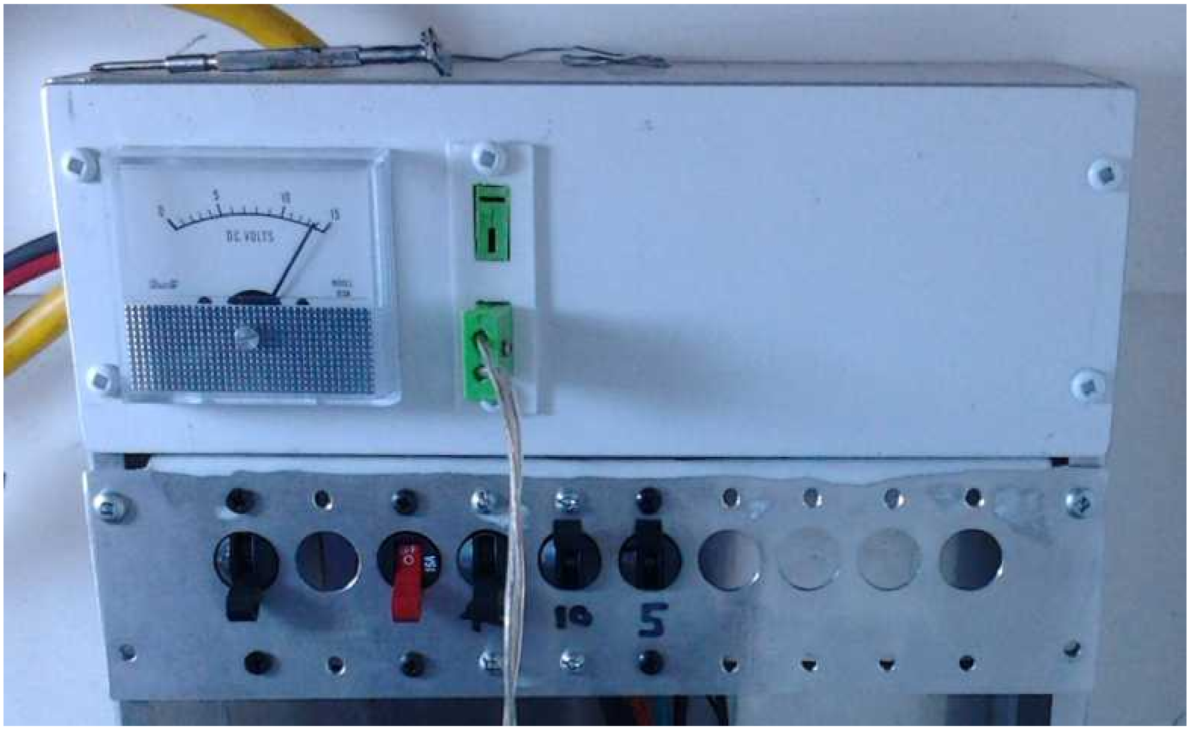
CAT Standard 12 Volt DC Sockets, Plugs, Wall Plates, etc.

12 VDC CAT Standard house wiring parts (green)
(Peltier element 12 VDC fridge is plugged in.)

The need for a standard for 12 volt DC wiring circuits being pressing, and no one else having come out with any sort of standard aside from the dinosaur car cigarette lighter type, I decided to define a standard that I thought most people would adopt, myself, by basing it on the common, practical and small size ATO/ATC automotive fuses. It is thus titled the Connectors, AT or "CAT" standard.

The approach is threefold:

1. a set of **specifications**
2. a set of **products** - which are here offered for sale
3. an upload of the **plastic parts designs** for the products to thingiverse.com so anyone with a **3D printer** can make the products.



12 VDC solar PV breaker panel with narrow plate convenience outlet.
(Plugged in: 12 V LED light that lit the closet for the picture.)
Aluminum plate 10" x 2.5" (thick, flat & no paint) with CNC drilled holes
for 10 Blue Sea Systems or equivalent breakers: 25$.
Copper bus bar goes to bottom of one end (main 12V) breaker and top of 7 others: 25$.
2 breakers are for between solar PV panels and DC to DC converter or other uses.

Here are the essential **Specifications**. There's a fair tolerance for dimensions except for the .025" blade thickness. A thicker metal such as .030" will expand the sockets, bending the grips so regular thinner blades fit loosely. Bent or twisted blades can also cause this problem. (It's not my fault!) Pretty much anything else that fits okay is fine.

Blade Center Spacing: 9.5mm (same as AT fuses).
Blade Orientation: The **negative** connector blade is in line, that is, the same as an AT fuse. The **positive** connector is crosswise to the AT fuse, that is, facing the same way as a 120 VAC wall plug.
Blade Contact Dimensions: 5mm x 8mm x .63mm ~(.2" x .32" x .025") (a bit longer than AT fuse blades to account for plug & socket plastic faces)
Blade Sockets: Pico .205 inch type blade sockets or any equivalent that works (the size AT fuses plug into. I hope somebody makes or will make some that are less touchy than Pico's!)
Voltage: 12 -1 to +2.5 volts, or 11.0 to 14.5 volts -- the CAT spec is for unregulated 12 volts, essentially for battery power supply. Battery chargers commonly output up to 14.4 volts. (A few chargers go even higher. Avoid those for wiring with CAT plugs and sockets.) Any equipment having this plug should be made at least to not self destruct if fed these voltages, up to 20% higher or 10% lower than 12.0 volts.

Here are the **Products**. Colors available are: White, Red, Green, Yellow, Black. All ABS plastic items are available in any of these colors.

Turquoise Energy CAT standard 12 volt DC Sockets, Plugs and Related Items	$ each	$ @ 3+	$ @ 6+
CAT Regular Socket (with Pico .205 crimp-on blade sockets and shell screw)	1.00	.95	.90
CAT Regular Plug (with solder-on blades and shell screw)	1.00	.95	.90
CAT Click-Lock Socket (with Pico .205 crimp-on blade sockets and shell screw)*	1.50	1.35	1.20
CAT Click-Lock Plug (with solder-on blades and shell screw)**	1.50	1.35	1.20

CAT Regular Socket, plastic shell halves only	.70	.65	.60
CAT Regular Plug, plastic shell halves only	.70	.65	.60
CAT Click-Lock Socket, plastic shell halves only*	.70	.65	.60
CAT Click-Lock Plug, plastic shell halves only**	.70	.65	.60
1110 Receptacle/Light switch Box Full Cover, Duplex side-by-side CAT socket holder	2.00	1.7 5	1.50
1110 Receptacle/Light switch Box "decor" inner square Cover, Duplex up-down CAT socket holder	2.00	1.75	1.50
Small panel cover, Duplex up-down CAT socket holder	1.75	1.50	1.25
Narrow panel cover, Duplex up-down CAT socket holder	1.50	1.25	1.00
CAT Car Cigarette Lighter adaper Socket (Puts a CAT socket in your cigarette lighter socket)	TBA		

* Click-lock sockets have a slot and protrusions to match click-lock plugs. They will also accept regular plugs.
** Click-lock plugs have a hood with a divider that helps shield and isolate the plug blades. They only fit into click-lock sockets.

Click-lock plugs & sockets, connecting
batteries and chargers in electric car.

CAT Sockets - Both the Regular and the Click-Lock Sockets can be used in-line on a cord, or inserted into one of the various mounting plates. The regular sockets connect only with regular plugs. The Click-Lock sockets connect with regular or click-lock plugs. (Click-lock sockets will stick out 8mm from the face of a wall plate.)

* bare plastic socket shell, two halves/parts
* sockets with Pico crimp-on

CAT Plugs

Regular and hooded Click-Lock plugs for the ends of wires. Regular plugs will fit regular or click-lock sockets. Click-lock plugs fit only click-lock sockets.

CAT Wall and Panel Plates

* Small Panel Plate - up-down duplex outlet
* "Square Hole" Plate - up-down duplex outlet
* 1110 Outlet Box Full Cover Duplex

Special adapters

* Car cigarette lighter socket (TBA)

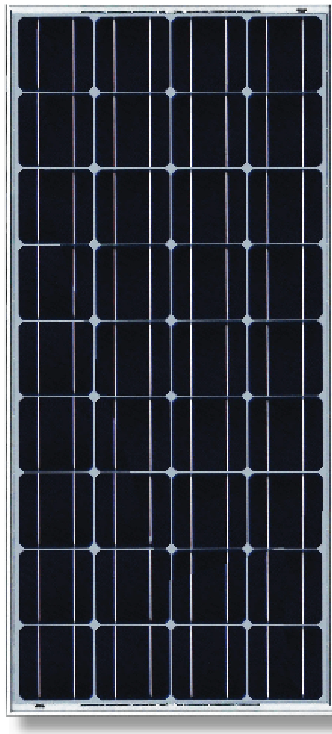
Here is the **Repository URL**, www.thingiverse.com , where the plastic part designs for CAT plugs, sockets and accessories can be downloaded for free for those who wish to make their own with a 3D printer.

Steel piece for folding .025" thick CAT pins to fit the plug shells.
Pico doesn't make the AT fuse size pins, only the sockets.

Miscellaneous

- Solar Panels
- Rare Earth Elements/Compounds & Other Chemicals

SOLAR PV PANELS (New)
(Cash & Carry Victoria BC Pickup Only)
HES 90 watt panels 225 $ + GST - In stock. (Other Panels/merchandise from HES **HESPV.ca** may also be ordered here.)



HES PV

HES-90 // 90Wp // 36-Cell Mono-Crystalline Solar Module

www.hespv.ca

HES solar modules with high efficiency crystalline solar cells, offers high charge current at a voltage suitable for both summer and winter temperatures. The cells are bonded to a special tempered solar glass for watertight integrity and a deep anodized aluminum frame makes them strong and rugged for all Canadian environments.

BUILT FOR CANADA

The HES-90 solar modules offer reliable battery charging in all Canadian climates. Their rugged design makes them a popular choice for industrial systems, remote homes and RV battery charging systems.

MECHANICAL STRENGTH

The rugged anodized aluminum frame mates with the HES pole and roof mounts for a strong and secure solar system. Panels may be installed in portrait or landscape.

PLUG AND PLAY WIRING

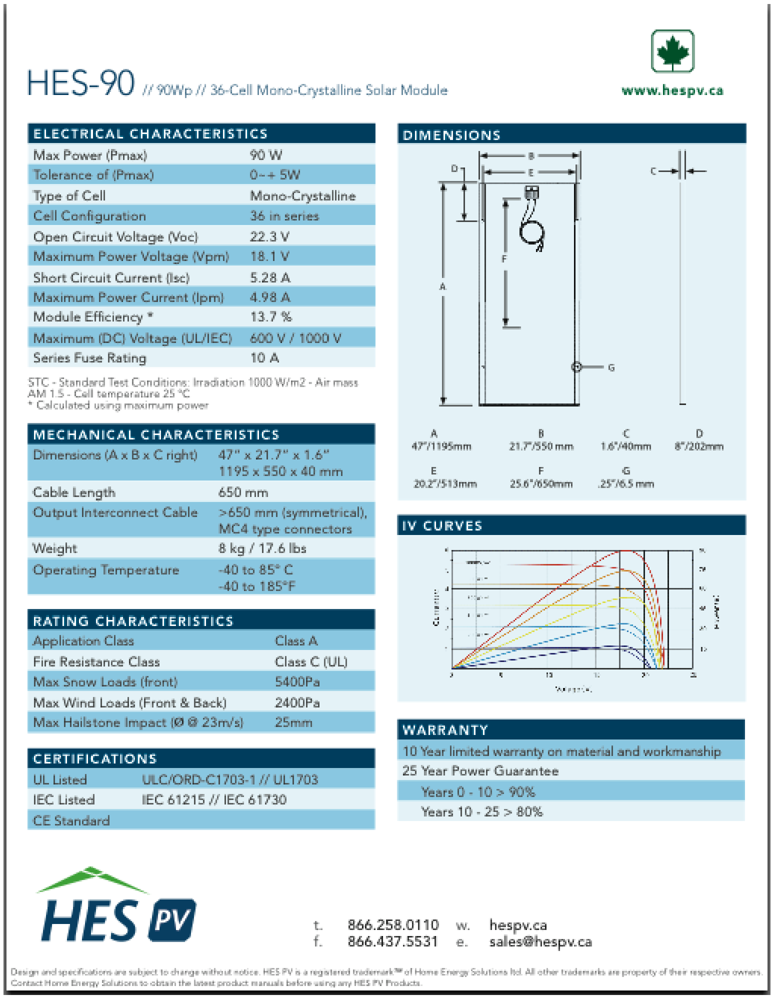
The HES-90 uses MC-4 type wiring connectors, and offers secure, plug and play electrical connections. Use the sunlight resistant HES MC Series cables to extend the array cabling up to 50 ft, or HES combiners to transition to conduit or Teck cable.

RELIABLE

10 year mechanical warranty and 25 year power output warranty ensure your solar system delivers power to your load.

CE LISTED PV CYCLE

CONTACT YOUR HES PV SOLAR PROVIDER TODAY



HES-90 // 90Wp // 36-Cell Mono-Crystalline Solar Module

www.hespv.ca

ELECTRICAL CHARACTERISTICS	
Max Power (Pmax)	90 W
Tolerance of (Pmax)	0~+ 5W
Type of Cell	Mono-Crystalline
Cell Configuration	36 in series
Open Circuit Voltage (Voc)	22.3 V
Maximum Power Voltage (Vpm)	18.1 V
Short Circuit Current (Isc)	5.28 A
Maximum Power Current (Ipm)	4.98 A
Module Efficiency *	13.7 %
Maximum (DC) Voltage (UL/IEC)	600 V / 1000 V
Series Fuse Rating	10 A

STC - Standard Test Conditions: Irradiation 1000 W/m2 - Air mass AM 1.5 - Cell temperature 25 °C
* Calculated using maximum power

MECHANICAL CHARACTERISTICS	
Dimensions (A x B x C right)	47" x 21.7" x 1.6" 1195 x 550 x 40 mm
Cable Length	650 mm
Output Interconnect Cable	>650 mm (symmetrical), MC4 type connectors
Weight	8 kg / 17.6 lbs
Operating Temperature	-40 to 85° C -40 to 185°F

RATING CHARACTERISTICS	
Application Class	Class A
Fire Resistance Class	Class C (UL)
Max Snow Loads (front)	5400Pa
Max Wind Loads (Front & Back)	2400Pa
Max Hailstone Impact (Ø @ 23m/s)	25mm

CERTIFICATIONS	
UL Listed	ULC/ORD-C1703-1 // UL1703
IEC Listed	IEC 61215 // IEC 61730
CE Standard	

DIMENSIONS

A	B	C	D
47"/1195mm	21.7"/550 mm	1.6"/40mm	8"/202mm
E	F	G	
20.2"/513mm	25.6"/650mm	.25"/6.5 mm	

IV CURVES

WARRANTY
10 Year limited warranty on material and workmanship
25 Year Power Guarantee
Years 0 - 10 > 90%
Years 10 - 25 > 80%

HES PV

t. 866.258.0110 w. hespv.ca
f. 866.437.5531 e. sales@hespv.ca

RARE EARTH ELEMENTS - CHEMICALS
(Metals have assay sheets - all high purity)

Dysprosium rare earth Metal - several "1/2 a golf ball" ingots, approx 185g each. -- 500 $ each
Gadolinium rare earth Metal - small chunks -- 60¢/gram
Erbium rare earth Metal - small chunks -- 40¢/gram

Neodymium oxide (purity unspecified, no assay sheet) -- 8 $/100gram package
Lanthanum Hydroxide (made from high purity lanthanum but purity of hydroxide unspecified) - 8 $/100g pkg.

Nickel Hydroxide (Battery quality) -- 8 $/100gram package; 70 $/kilogram package

---

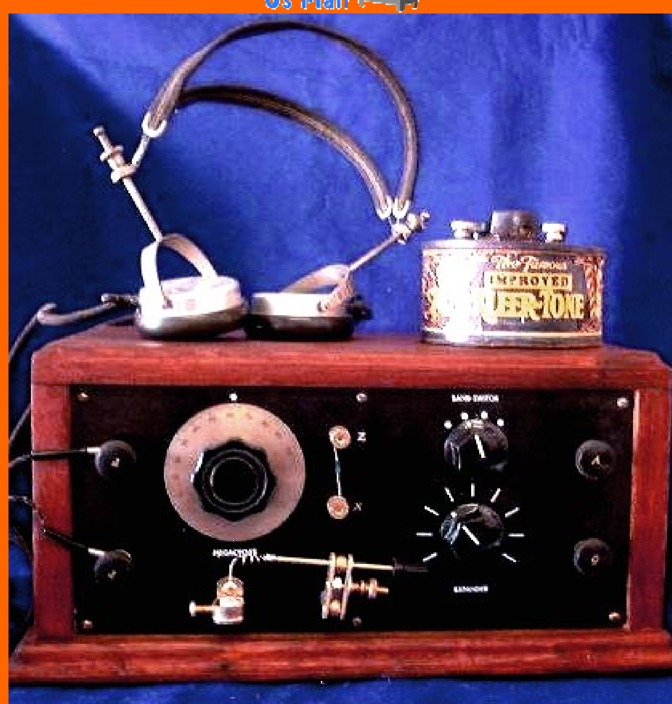
Please don't hesitate to write with comments or questions. Feedback is important!

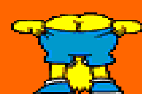
Craig Carmichael
Craig @saers.com

www.TurquoiseEnergy.com
Victoria BC Canada
250-384-2626

"CRYSTAL RADIOS" Built to Order

Coming soon, NEW Short Wave Crystal Receivers. Email me if you have a special radio you want built.





This ain't the End, man, more crystal sets are coming.

Filed Under: Free Energy Devices (https://www.homemade-circuits.com/category/free-energy-devices/)

How to Collect Free Energy from Atmosphere – Circuit Diagram Attached

Last Updated on November 14, 2017 by Swag (https://www.homemade-circuits.com/author/swagatam/)

A free energy collector circuit helps to convert surrounding radio frequency waves to electric power and can provide 40 watts to 10 watts indefinitely.

Contents [hide]

The Circuit Concept

An option to increase the output power is achievable through proper set-up of an antenna. Placing an antenna in a close proximity of a large metal object helps generate additional power.

More Projects: Small Circuits Projects (https://www.homemade-circuits.com/?s=transistor+circuits), IC 555 Hobby Projects (https://www.homemade-circuits.com/?s=555+circuits)

The wire of an antenna should be more than 150 feet long, which has to be placed horizontally on a higher platform to derive the best result.

The more the higher an antenna is set, the more it is able to act efficiently. However it is advisable to keep the circuit closer to an antenna.

The proposed free energy collector circuit on the other hand, also acts as a passive detector. As the large metal object passes wave, there is an increase in power. One major usage of this process is in the field of volcanic studies.

Selecting the Antenna

The sensitivity of an antenna is capable to detect variation of energy from earth and is often used to receive warning signal for a possible seismic activity.

So it can be summed up that the placement of an antenna is very much crucial for a better output. Also one can use many of these circuits to construct and connect their inputs together, to produce ample energy to run electricity in a house. However to note, each unit needs their own antenna to construct the same.

The Radio Frequency power varies based upon a location. If the set-up location is close to a city or in close proximity to the transmitters, which generates high level of Radio Frequency; leads to an optimal performance.

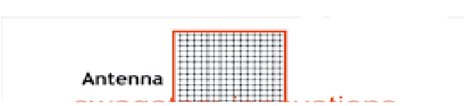
If you are excited to generate free power at your house from the atmosphere, then you can perform some experiment with different length and size of an antenna.

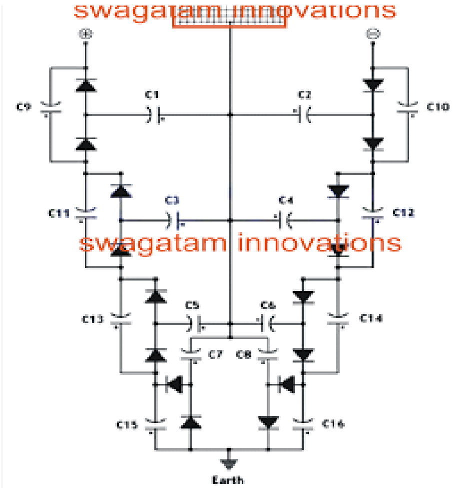
Altitude is Crucial

However keep in mind to place the antenna on a higher location for better result. During construction it is also necessary to keep in mind the earth ground of the circuit has to be properly conductive. The earth ground should also consist of metallic, conductive pipe or rod.

Submitted by: Dhrubajyoti Biswas

Circuit Diagram





(https://www.homemade-circuits.com/wp-content/uploads/2013/06/freeenergycollectorcircuit-1.png)

Parts List

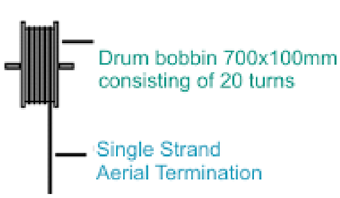
All Diodes are 1N4148

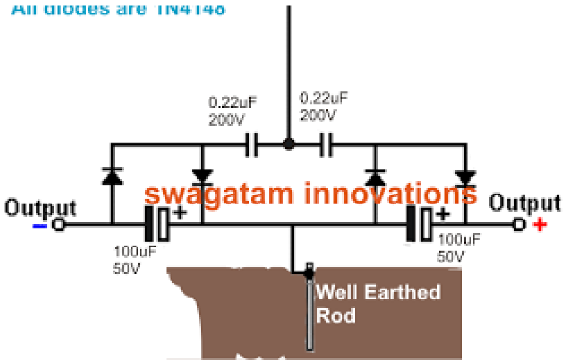
C1---C8 = 0.22uF/100V mylar

C9----C16 = 33uF/25V electrolytic

Improving the Free Energy Device

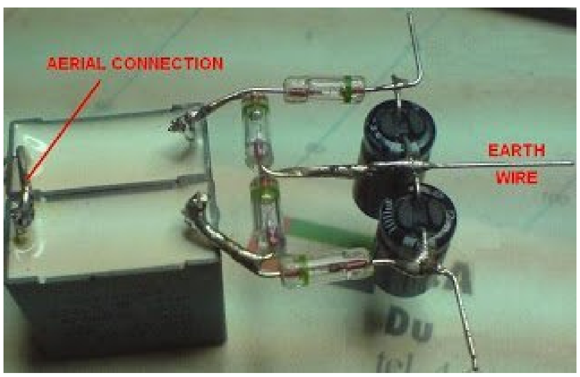
The following more comprehensive free energy deriving circuit design was forwarded to me by one of interested readers of this blog Mr.Prashanth Dhonde.



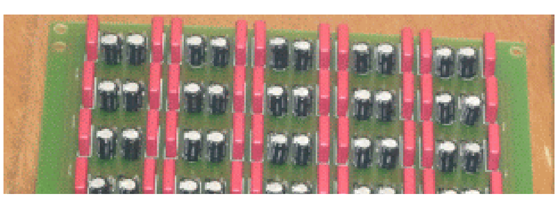


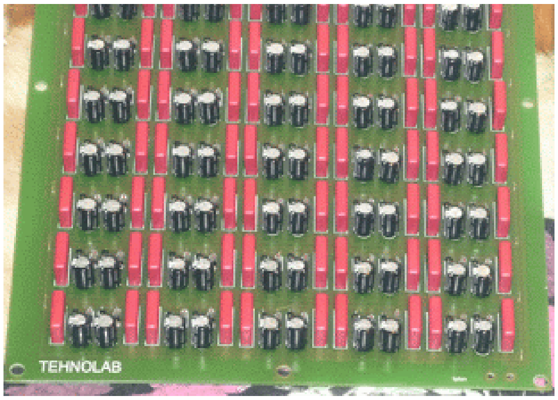
(https://www.homemade-circuits.com/wp-content/uploads/2013/06/freeenergyfromatmosphere.png)

More info on the above design:

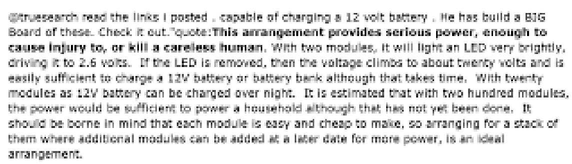


(https://www.homemade-circuits.com/wp-content/uploads/2013/06/makefreeenergyathome.jpg)





(https://www.homemade-circuits.com/wp-content/uploads/2013/06/freeenergyprototype.gif)


@truesearch read the links I posted . capable of charging a 12 volt battery . He has build a BIG Board of these. Check it out."quote:**This arrangement provides serious power, enough to cause injury to, or kill a careless human.** With two modules, it will light an LED very brightly, driving it to 2.6 volts. If the LED is removed, then the voltage climbs to about twenty volts and is easily sufficient to charge a 12V battery or battery bank although that takes time. With twenty modules as 12V battery can be charged over night. It is estimated that with two hundred modules, the power would be sufficient to power a household although that has not yet been done. It should be borne in mind that each module is easy and cheap to make, so arranging for a stack of them where additional modules can be added at a later date for more power, is an ideal arrangement.

(https://www.homemade-circuits.com/wp-content/uploads/2013/06/makingfreeenergy.png)

725

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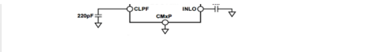
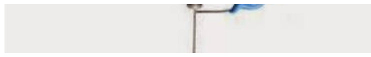


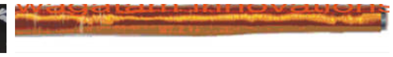
Instrumentation IC Guide



Free 200 Volts Just Above your Head

homemade-circuits.com

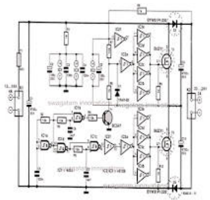
[Video] Paste Dispenser



Circuit for Making Free Electricity from Atmosphere

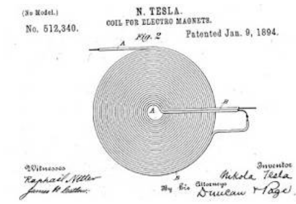
homemade-circuits.com

Industrial Data Loggers



High Current Voltage Doubler Circuit

homemade-circuits.com



Free Energy from Induction Cooktop

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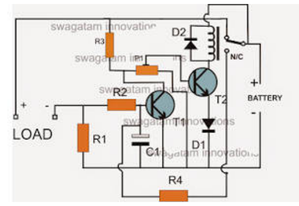

Low Battery Cut-off and Overload Protection Circuit.

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Homemade Circuits

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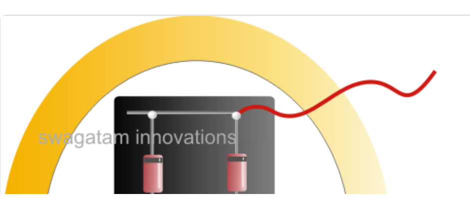

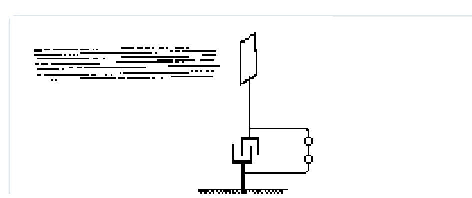

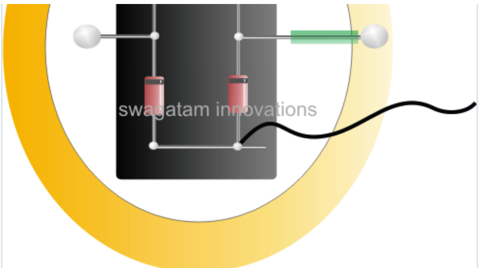

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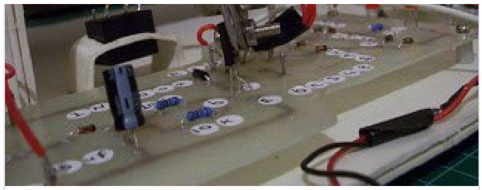
Piezo Mat Electricity Generator Circuit (https://www.homemade-circuits.com/piezo-mat-electricity-generator-circuit/)



(https://www.homemade-circuits.com/building-sec-excitor-circuit-by-steven/)

Building a Sec Exciter Circuit – By Steven Chiverton (https://www.homemade-circuits.com/building-sec-excitor-circuit-by-steven/)

(https://www.homemade-circuits.com/understanding-free-energy-receiving/)

Free Energy Receiving Concept – Tesla Coil Concept (https://www.homemade-circuits.com/understanding-free-energy-receiving/)

Circuit Calculators

Transistor BJT base Resistor Calculator Software (https://www.homemade-circuits.com/transistor-bjt-base-resistor-calculator-software/)

LC Resonant Frequency Calculator Software (https://www.homemade-circuits.com/lc-resonant-frequency-calculator-software/)

Ohm’s Law Calculator Software (https://www.homemade-circuits.com/ohms-law-calculator-software/)

LM317, LM338, LM396 Calculator Software (https://www.homemade-circuits.com/lm317-lm338-lm396-calculator-software/)

Inductance Calculator Software for Coils (https://www.homemade-circuits.com/inductance-calculator-software-for-coils/)

LED Resistor Value and Wattage Calculator Software (https://www.homemade-circuits.com/led-resistor-value-wattage-calculator-software/)

Capacitance, Reactance, and Admittance Calculator Software (https://www.homemade-circuits.com/capacitance-reactance-and-admittance-calculator/)

IC 555 Timer Monostable Circuit Calculator Software (https://www.homemade-circuits.com/ic-555-timer-monostable-circuit-calculator-software/)

IC 555 Astable Timer Circuit Calculator Software (https://www.homemade-circuits.com/ic-555-timer-astable-circuit-calculator/)

Comments

Did not find what you wanted? Please specify your requirement in the comment box below, we'll get back to you with the solution ASAP....

sharaf (https://www.blogger.com/profile/02176852415494721216) says

Dear Swagatam,
This is very good concept
What type of antenna I can use
Can I make Antenna myself,if kindly give guide line
as per above circuit how many volt and watt we can get out put.
Best Regards,
Sheraf

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

Dear Sharaf,

Thanks!

Actually the article was submitted by one of the avid readers of this blog, so personally I am not sure about the exact details of this experiment.

Reply

Anonymous says

sir this will work in day as well as night also…

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

yes, round the clock….

Reply

Anonymous says

Sir please give the list of things used in this project…

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says
it's given in the diagram.

Reply

Anonymous says
plzz sir send me list of things use its my request….

Reply

maksim garbaly (https://www.blogger.com/profile/17349284539125566961) says
I made a fractal antenna and it's has a capability to capture more variety of waves giving more power

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says
thanks for updating the info

Reply

SHIV-FOUNTAIN (https://www.blogger.com/profile/12486513453141239751) says
Hi dear sir,
Can you please provide us high power led driver's all wattage circuit digram
my email. id is swapnilsinalkar@rediffmail.com (mailto:swapnilsinalkar@rediffmail.com)

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says
Hi Shiv,

You can try the following design:

https://www.homemade-circuits.com/2013/06/universal-high-watt-led-current-limiter.html (https://www.homemade-circuits.com/2013/06/universal-high-watt-led-current-limiter.html)

Use LM196 for the IC if the requirement is upto 10amps.

Reply

Anonymous says

bhai ,
output tho bata do

Reply

Anonymous says

is it working?

Reply

achilles hector (https://www.blogger.com/profile/13316234132440706379) says

hi sir!!!
1. On the last picture, can you give me the schematic diagram?

thanks in advance!!!!

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

it's the same as the second diagram, just add many of them in parallel.

Reply

Raymund Delfin (https://www.blogger.com/profile/14753183174013514237) says

Hi sir,

I found this link:

http://frenergy.ca/tapping-into-200-volts-positive-of-free-unlimited-and-unmetered-pure-electrical-energy.html (http://frenergy.ca/tapping-into-200-volts-positive-of-free-unlimited-and-unmetered-pure-electrical-energy.html)

On this design, http://frenergy.ca/wp-content/uploads/2013/05/pyramid-flux-capacitor.bmp (http://frenergy.ca/wp-content/uploads/2013/05/pyramid-flux-capacitor.bmp)

what should be the proper capacitor/diodes to use? or any suggestions for this.

Thank you.

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

Hi Raymund,

The blue cap is 0.0002uF/5000V
The electrolytic cap looks like a 22uF/100V
The diodes could be 1N4148 or BAT30

Reply

Rohit (https://www.blogger.com/profile/13174722612309812021) says

Do you think 150 feet antenna is practical??

Reply

Anurag (https://www.blogger.com/profile/09834831607530777868) says

One of the best circuits ever seen. If I use any voltage booster IC(output adjustable one) from National Semiconductor or Texas Instruments and configure it for lets say 6V then if the voltage at the input increases or decreases will I get 6V at the output? If the output changes will the current change or voltage will change. Can I use 1N4007 diodes instead of 4148, 1N4007 is used for rectiication but whats the main difference between the two.

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

Thanks! I don't think ICs will work here.
1N4007 cannot be used since they are not specified for high speed detection. 1N4148 react much faster compared to 1N4007.

Reply

prasanta sarkar (https://www.blogger.com/profile/02098567562187571344) says

what about out put voltage??? and anyone make this circuit????is this working…Pls tell

Reply

shadab karnachi (https://www.blogger.com/profile/06270167366306027745) says

hi,
I am looking for an advanced electronic based project on changing weather and climate. It could be and new type measuring device or analysing device using electronics. Measuring weather attributes like temperature, daily sun shine hours, humidity, wind,
precipitation, etc will do. please please tell me if you have any one, even from outside your website. Iam a 9th grader, and i want to take my project to the national level.please give me the link of the project you know or tell me yourself about any project. It would be an great pleasure.

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

Hi, this could be a complicated design and would need microcontrollers, presently I do not have an appropriate info regarding the subject, if I happen to come across one I'll surely let you know about it.
Thanks!

Reply

shadab karnachi (https://www.blogger.com/profile/06270167366306027745) says

hi,
I have microcontroller, currently i have atmega 16 and I program with a software called bascom AVR and then compile it and then feed the program with ponyprog 2000 software, using serial port. Please send me the project with microcontroller.

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

presently I do not have an appropriate info regarding the subject, if I happen to come across one I'll surely let you know about it.

Reply

shadab karnachi (https://www.blogger.com/profile/06270167366306027745) says

thanks,
but please try to get that within a month. It would be a great pleasure. I have to present it soon.

again thanks,
with regards.

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

I'll try my best. Thanks

Reply

mawuli dugbartey (https://www.blogger.com/profile/13248897066654377490) says

Eng. Swagatam please I need a simple circuit that can reduce 12v/60Ah to 12v/20……25AH for my homemade inverter. thank you.

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

mawuli, if your inverter is rated to work with a 12V supply you can comfortably use the 12V/60AH or any higher AH battery without worrying…unless the voltage is increased AH will not cause any harm to the inverter.

Reply

mawuli dugbartey (https://www.blogger.com/profile/13248897066654377490) says

thank you Eng, Swagatam, but the reason why i need this solution is because the battery turns to burn the components and the jumpers on the circuit board.
Here is the link to the circuit i built.. https://drive.google.com/file/d/0B15SzCeSV14XekxNMEV6dl9YY2c/edit?usp=sharing (https://drive.google.com/file/d/0B15SzCeSV14XekxNMEV6dl9YY2c/edit?usp=sharing)

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

the image is not opening,

anyway, check the condition without any load…. if still it starts burning would indicate a malfunction in the unit.

unless the voltage is increased AH will not cause any harm to the inverter.

Reply

mawuli dugbartey (https://www.blogger.com/profile/13248897066654377490) says

please Eng. Swagatam can you also sadjust a simple inverter circuit diagram the can power electronics and inductive load

please Eng. Swagatam can you also sadjust a simple inverter circuit diagram the can power electronics and inductive load.
thank you
sorry for bordering you.

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

you can try any 4047 based inverter design, and add a 0.22uF/400V capacitor at the output of the inverter….. this will fulfill your requirement reasonably.

Reply

mawuli dugbartey (https://www.blogger.com/profile/13248897066654377490) says

Thank you Eng. Swagatam I appreciate what your help may God richly bless you.

Reply

Emmanuel Eli (https://www.blogger.com/profile/06905360229977428441) says

Dear
Swagatam, please i want a circuit that will changeover between two
batteries for an inverter while the strong battery is powering the
inverter, the weak one is bieng charged automatical by a charger
connected to the inverter…. Please I want to know if it is possible
thank you in advance.

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

Dear Emmanual,

If you have a low battery indicator in your existing inverter then you could probably try the following design:

https://www.homemade-circuits.com/2012/11/automatic-dual-battery-changeover-relay.html
(https://www.homemade-circuits.com/2012/11/automatic-dual-battery-changeover-relay.html)

Reply

Emmanuel Eli (https://www.blogger.com/profile/06905360229977428441) says

thank

thank
you for your quick respond, but the inverter am having is a homemade 555 squarewave inverter I made following some of your post and it does not have low battery indicator, so if you could please help me with a simple circuit on that so that I can continue from the previous solution circuit you gave.thank you once again.

Reply

Emmanuel Eli (https://www.blogger.com/profile/06905360229977428441) says

Dear
Swagatam
another little confusion is the kind of charger circuit I will need in charging the dual configuration setup of the batteries, because each of the batteries am going to use have a high "AH" 12v 100AH and 12v 120AH. Meaning do I use a single charger or a split charger type.thanks you once more.

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

Dear Emmanuel,

A split charger would be preferable, you can build the following design, it is supposed to charge the batteries in a split manner by selecting the battery according to their charge levels:

https://www.homemade-circuits.com/2014/05/twin-or-split-battery-charger-circuit.html (https://www.homemade-circuits.com/2014/05/twin-or-split-battery-charger-circuit.html)

Reply

Emmanuel Eli (https://www.blogger.com/profile/06905360229977428441) says

Thank
you Mr. Swagatam… I wl post you the images when and am done and I wl also let you know when I face any difficulties…thank you once again.

Reply

Emmanuel Eli (https://www.blogger.com/profile/06905360229977428441) says

Mr.
Swagatam, and also do I have to combine the two circuit diagrams which is the dual battery changerover and the split charger? Thank you.

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

Hi Emmanuel, the last circuit link above will changeover from one battery to the other, so any other circuit won't be required.

Reply

Emmanuel Eli (https://www.blogger.com/profile/06905360229977428441) says

thank you Mr. Swagatam
I appreciate your kindness.

Reply

eshkariel tapiador (https://www.blogger.com/profile/14615244102267469941) says

Is this inspired by Tesla's Generator?

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

yes that's right

Reply

James Lane (https://www.blogger.com/profile/10608022543348153745) says

I have completed the circuit and it works great, but in the bottom picture there are 50 circuits. Any idea if they are connected in series or in parallel? I have tried series to increase the voltage and it keeps decreasing rather than increasing. Any idea how you can hook this circuit up in series?

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

That's great and interetsing, because most people have a skeptical view about such concepts,

in the bottom image the configurations are in parallel in order to increase current gain and the overall power of the output….it could be done in parallel first and then those parallel strings could be further put in series for getting a

sustained boosted voltage

Reply

sarib zafar (https://www.blogger.com/profile/12258976233688899104) says

Hi sir !!
Could you please tell the output form, i mean dc or ac and if ac so in which waveform.
Thanks !

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

Hi sarib, the output will be DC since it would be from the capacitor's stored energy which is always DC

Reply

Prasanna M.shetty (https://www.blogger.com/profile/06412449645411441118) says

dear sir pls tellme swg of wire its length r whitch type antena will be useable to make this circuit

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

dear prasanna, you can use any standard flexible wire for it which we normally use in our home wiring. …….1/18 could be tried

Reply

Syed Arham (https://www.blogger.com/profile/08119427638513485665) says

Sir can you suggest me a circuit in which first we charge capacitors with 12v then these capacitors give accurate 12 or 11v just for 5 or 10sec

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

Syed for this you may have to employ huge caapcitor may be upto 10000uF, it will also depend on the discharge rate (mamps) of your application.

Reply

Syed Arham (https://www.blogger.com/profile/08119427638513485665) says

Thanks

Reply

cj vignesh (https://www.blogger.com/profile/10506548807454596976) says

swagatam i am going to do this project.if i start did i get output .what type of material should be used for antenna

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

CJ, actually I have not yet tested this circuit, so I am not sure abut the results, however many have tested and have been successful in getting reasonable outputs….

Reply

Syed Arham (https://www.blogger.com/profile/08119427638513485665) says

Sir 0.22uf capacitor is not available in my city can you suggest me equivalent. And if i connect a 20ma led with one circuit then does it glow or burn out.

My home is on 2nd floor then the antenna is necessary or not..i means that i will use a shorter anntena or iron rod

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

Hi Syed, I have not yet tried this practically so cannot say about the results, but an LED will not burn I think, because the setup may not be capable of generating that much power.

0.22uF is not acritical value, you can any other capacitor with nearby values.

antenna is a must and needs to be included no matter on which floor you are, without antenna the circuit may not produce the intended outputs

Reply

fidel catsro (https://www.blogger.com/profile/02176426917689425367) says

I tried making the simpler circuit above some years back after seeing it on you tube charging a handphone, it failed to work, not sure if its because of failed components or because it simply doesn't work

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

the output could be too trivial to notice….perhaps many such circuits needs to be connected in parallel to achieve anything that might be worth considering..

Reply

fidel catsro (https://www.blogger.com/profile/02176426917689425367) says

anyone trying to make this circuit will also have to be extra sure to get genuine germanium diodes which have low forward voltage and careful when soldering because they are very sensitive and easily damaged..

Reply

Janee Edward (https://www.blogger.com/profile/08694606142894467768) says

You can make 20 of this and use vortex connection to get high Wattage Output. By Vortex, I meant Directing each out put to separate caps each and then connecting the caps in series using a DIODE.

Reply

henry brown (https://www.blogger.com/profile/15001136636447304180) says

Amazing when connected correctly, low voltage yet great output

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

can you explain it in detail?

Reply

eshkariel tapiador (https://www.blogger.com/profile/14615244102267469941) says

Hi Engr. Swagatam,
Can you make a topic about tesla's patent "Apparatus for utilizing radiant energy"…tnx

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

Hi eshkariel, I will surely research the subject and try to post a related article in this blog.

Reply

eshkariel tapiador (https://www.blogger.com/profile/14615244102267469941) says

Hi Engr. Swagatam,
Can you make a topic about tesla's patent "Apparatus for utilizing radiant energy"…tnx

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

it seems, actually these concepts never worked satisfactorily according to me, otherwise we would have seen these being used in every home by now…

Reply

soon time (https://www.blogger.com/profile/04882695272652115806) says

Hello sir
Really work very well
But ask …!
Does it work on mobile networks Trdat – – 3G – 4G – because I live coverage area is too weak to connect to dial + Connectivity via USB modem

Reply

soon time (https://www.blogger.com/profile/04882695272652115806) says

Hello sir
I have some problems – about the reception of mobile phone signal – and the weakness of surfing the Internet – via USB modem – making antenna alone but also indicate weak dwell signal area – and I found booster mobile signal – but it's expensive – Is there a small semi to meet this work and get on the circle a good signal

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

Hello soon time,
sorry I do not have much idea regarding this subject, it could be quite complex to find an easy solution for it.

Reply

Unknown (https://www.blogger.com/profile/06397425412330417447) says

hi Swagatam Majumdar,

i am very impress when i see your website by mistakly. I am software engineer but from chield hood i like rnd of rnd,tv,tapes and computer repairing but many time i am unsuccessful due to no knowledge of electronics or electrical education.
i want to learn circuits from ABCD what i do.
I am regular update with new software but circuit level i am zero. Can you given me suggestion for i learn or not. If not then no problem if yes then give me guidance.

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

sure, I'll try my best to teach you electronics, you can ask any specific question related to electronics and get it solved from me.

Reply

Anonymous says

is it correct that c7 and c8 are reverse polarity compared to c1 – c6??
Can I use voltage multiplier to increase voltage since it has constant power source??
anyway..I'm going to start building this one… :D..Hope it works :/

eshkariel

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

I took this circuit from another site so I am not entirely sure about its working and the results….wish you all the best!

Reply

Jade Mark Talaboc (https://www.blogger.com/profile/07357474056594137971) says

hello swagatam

hello swagatam,

does this comes with a high power output?

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says
hello mark, no it doesn't…

Reply

s (https://www.blogger.com/profile/01096364000437046776) says
All the capacitors are reversed on the left side of the schematic. I built it and it didn't work until I corrected this.

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says
Thank you for updating the info!

Reply

Ali F.T (https://www.blogger.com/profile/10722111897734016878) says
Dear Swagatam Majumdar

I created this circuit but it generated 0.1 volt and need to time about 2 min for reaching to 2 volt and when i use this circuit by a very low amp LED this circuit discharge suddenly and again requires 2 min time for charging.

Please help me and explain what can i do about voltage that it generates 2 volt at first and does not need to time for charging.

Best Regards

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says
Dear Ali, it will probably depend on the antenna size, try with a more bigger antenna and see if that improves the results…

Reply

Deogratia Nkwenti (https://www.blogger.com/profile/13305401639124457538) says

Dear Sir.
Please i wish to build this circuit for my project as i live in a suburb with no electrical energy, now my question is, Can i use the circuit and connect it to a DC Car batterry so for it to charge then use an Inverter to step up the voltage so to macth my requirement? i will appreciate your help sir.
Thanks.

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

Dear Deogratia, the above circuit is only for experimental purpose, it cannot be used for running a house…it won't produce that much power…

Reply

Deogratia (https://www.blogger.com/profile/13405639319259548586) says

Thank you very much sir, so you mean there is no way to step up the voltage to any way that can charge a DC battery? i guess if the circuit can charge a batterry then it can push an inverter that can supply medium equipments, i am just asking if the idea can work out well via experiment… thanks for your time and i look forward to be hearing from you…

Reply

Swagatam (https://www.blogger.com/profile/13783312838408713408) says

You are welcome, Deogratia…The circuit will need to be extremely huge to accumulate the amount of energy required for charging a battery, in a limited scale it would be quite ineffective

Reply

Keith says

I simulated the circuit described and make it available here http://tinyurl.com/y6wcb2b5 (http://tinyurl.com/y6wcb2b5) . It might look different, but electronically it is exactly the same. One can experiment with different load resistors. It is quite simple a negative and positive voltage multiplayer.
Additional Notes.
1. If you know the altitude of your antenna above ground, you can guesstimate the atmospheric potential at that altitude

1. If you know the altitude of your antenna above ground, you can guesstimate the atmospheric potential at that altitude with the formula given so that you can determine safe and appropriate voltage ratings for your capacitors as well as be aware of handling while they are charged. Make sure to double that to consider days in which the atmosphere is more charged. Do not underestimate the importance of safety when handling capacitors, charged or not. The capacitors described don't store much energy so they are generally safe but people are likely to modify the circuit potentially making it very dangerous to handle. It is well known there is an electrical potential between ground and the altitude above of an antenna or charge collector. On the other hand, what this circuit does is harnesses stray electromagnetic fields, and RF noise. Yes it is wireless transmission of energy, but it is not atmospheric energy.

Reply

Swag (http://www.homemade-circuits.com/) says

Thanks Keith, that looks great, however how can the simulator estimate the amount of potential difference available in the atmosphere, because that's the key element behind the success of this experiment.

Reply

Okachi Johnson says

HELLO Swagatam thanks for ur tutorials .plz help me with the answers to these questions
1, Is mylar capacity polarized + & –
2.must the antenna be up to 150feet be it works
3. I used 0.22uf/100v electrolyte caps; is it accepable,although no single output
4. what type of wire should i use for the antenna
5. plz must i use earth materials for the earthing
I appreciate your response

Reply

Swag (http://www.homemade-circuits.com/) says

Hello Okachi, sorry, I cannot suggest personally anything regarding this concept because this article was referred from other forums and websites….please do it as per your own understanding and evaluations.

Reply

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11

Low Cost Prototype of an Outdoor Dual Patch Antenna Array for the Openly TV Frequency Ranges in Mexico

M. Tecpoyotl-Torres[1], J. A. Damián Morales[1], J. G. Vera Dimas[1], R. Cabello Ruiz[1], J. Escobedo-Alatorre[1], C. A. Castillo-Milián[2] and R. Vargas-Bernal[3]

[1]*Centro de Investigación en Ingeniería y Ciencias Aplicadas (CIICAp-UAEM)*
[2]*Facultad de Ciencias Químicas e Ingeniería (FCQeI-UAEM)*
[3]*Instituto Tecnológico Superior de Irapuato (ITESI)*
Mexico

1. Introduction

In this research, we developed a dual antenna array for the household reception of openly analogical television (TV) frequencies. This array was designed on Flame Retardant-4 (FR-4) as substrate, in order to obtain a low cost prototype.

The interest in this area is because of the fact that the openly TV is one of the most important communication media in our country. From information supplied in 2009 in the National Survey over availability and use of Technologies, it reveals that the 72.8% of the population uses the services of the openly TV (Instituto Nacional de Estadística, Geografía e Informática [INEGI], 2009). A TV can be found in almost all homes of the country, but only 13.6% correspond to digital technology, while only a half of homes with a digital TV requires signal payment. The availability of TVs in Mexican homes in 2010 remained without severe changes (INEGI, 2010).

Since the operation frequencies ranges are not so high, and then the antenna sizes, obtained directly from the design equations are very large. Therefore, the scaling is a necessary step in order to reduce the antenna sizes to achieve its easy manipulation.

As it is well-known, a very simple common example of antennas used for household reception of TV is the Yagi-Uda (or Yagi) array, where the length of the dipoles established the phase of the individually received signals. An example of a commercial Yagi-Uda antenna designed for channels 2-13 can be found in (Balanis, 2005). The TV transmission has the polarization vector in the horizontal plane so that the array must also be horizontal (Melissinos, 1990).

The evolution of the antennas designed in order to improve the openly TV reception has notably changed in the last years, in such a way, for outdoor use it is possible to find the large aerial antennas, fixed or with an integrated rotor, under different geometries, such as

single dipoles and combinations of Yagi arrays. A decrease in sizes is noted in some cases. An example of design development of antenna for TV transmission for outdoor broadcasts can be found in (Rathod, 2010), at 750 MHz as the center frequency, where the antenna was fabricated on FR-4, with substrate sizes of 40x40 cm^2. This antenna was designed for the study of rural areas in India.

For indoor use, there are also several options of relative small sizes, and under different geometries. Recently, new commercial options based on patch or microstrip antennas have been proposed, which can be located on the rear part of the TV display that means, hidden to the user. But there is not available technical information about its design. An UHF planar O-shaped antenna has been proposed and studied (Barir & Hamid, 2010), which was fabricated on FR-4, with a dimension area of 20x20 cm^2, with an enough bandwidth to cover Indonesian broadcasters.

Other special case is formed by the antennas for TV reception in cars. In (Neelakanta & Chatterjee, 2003), a V-structure dipole, which is part of the dipole families, has been conceived for the purpose of TV reception (VHF/UHF bands), which gives a directional pattern with horizontal polarization. An active loop antenna suitable as automobile television receiving antenna, for channels 13-62 (from 470-770 MHz in Japan) can be found in (Taguchi et al., 1996).

In (Wang & Lecours, 1999), an antenna array with orthogonal polarization finds applications in Direct Broadcasting Systems (DBS), Personal Communication Services (PCS) and Indoor Communication Systems (ICS). As the current DBS technology uses both horizontal and vertical polarizations, and then the microstrip arrays with orthogonal polarizations are needed. While in PCS and ICS, waves are scattered by the environment and the signal takes several paths from a transmitter to a receiver, with resulting fluctuations in amplitude because of multipath fading effect. To overcome this effect, it is necessary to implement a polarization diversity technique, for which antenna arrays with orthogonal polarizations and very low cross couplings are needed.

On the other hand, it is recognized as a common problem in TV to the multipath reception, where signals from the same station can reach the reception antenna by two or more distinct paths which differ significantly in length (web site: http://www.electusdistribution.com.au/images_uploaded/tvrecepe.pdf, May 2011).

In (Brown et al., 2007) it was shown that dipoles and other linear antennas can sometimes, although not always, have a large degree of polarization diversity if they have different polarization orientations. A typical configuration of polarization diversity system consists of one transmit and one dual-polarized receive antenna (i.e., maximal diversity order of two) (Kapinas et al., 2007).

Dual linear polarization is characterized by two orthogonal linear polarizations on the same antenna. Dual polarization antennas have the benefit of allowing two signals, with different orientations, to be broadcast or received on the same antenna (Smith, 2008).

1.1 Mexican TV system

The TV channels in Mexico, in the VHF band are divided in two sub-bands: From 2 to 6, they are in the range from 54 MHz to 88 MHz, and from 7 to 13 are transmitted from 174

MHz to 216 MHz. Some channels are divided between the two most important television companies as follows: the broadcast channels of Televisa are 2, 4, 5 and 9 (a repetition of channel 2); and the corresponding of TV Azteca are 7 and 13 (channels in operation in D.F. in 2006 (Jalife & Sosa, 2007)). Some channels can be transmitted in different frequencies depending of the corresponding Mexican states.

In addition, in each Mexican state, there are additional channels by concession, for example in Morelos, channel 6 corresponds to the Instituto Politécnico Nacional, 3 to the Government of the Morelos State, 11 to Radio Televisora de Mexico Norte S. A. de C. V., 28 to TV Azteca, and 22 to the Presidencia Municipal de Zacatepec (Comisión Federal de Telecomunicaciones [COFETEL], 2008). From channels 14 to 83, they correspond to UHF band.

In our country, for some analogical active channels, temporary it is assigned an additional channel (mirror) to transmit the same information, but with a digital format, until the transition to the digital terrestrial television in Mexico concludes. The last period of transition was planned from 2019 up to 2021, but recently it has been established until December 31, 2015. The temporary digital channels assigned are shown in Table 1. The analogical channels will be returned when the transition will be finished.

TV analogical channel	TV digital channel
2	48
4	49
5	50
7	24
9	44
13	25

Table 1. Digital assigned channels as mirrors.

In this works, our interest is focused in a patch antenna array prototype for openly TV frequency ranges in Mexico, with polarization diversity, for outdoor use. In Section 2, the design of the antenna array will be described and the corresponding simulations will be provided in Section 3. The first tests results are discussed in Section 4, and finally, in Section 5, some concluding remarks are given.

2. Antenna array design

Considering only the two current VHF frequency ranges of the openly TV in Mexico, we chose as operation frequency to 71 MHz for the design of the rectangular patch antenna, which will be used as the base of the prototype patch antenna array. This frequency corresponds to the central frequency of the first sub-range of frequency of VHF. The rectangular antenna was designed using the well-known equations (Balanis, 2005 and Garg et al., 2001):

For the patch width:

$$W = \frac{c}{2 f_o \sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

where c is the constant speed of light in vacuum, ε_r, the dielectric constant substrate and f_0, the operating frequency equal to 71 MHz.

The effective dielectric constant:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{-1/2} \quad \text{if} \quad \frac{W}{h} > 1 \tag{2}$$

The effective length is calculated using:

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\varepsilon_{reff}}} \tag{3}$$

The two increments in the length, which are generated by the fringing fields, make electrical length slightly larger than the physical length of the patch:

$$\Delta L = 0.412h \frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \tag{4}$$

The patch length is given by:

$$L = L_{eff} - 2\Delta L \tag{5}$$

The length and width of ground plane (and the substrate), are given by:

$$L_g = 6h + L \quad \text{and} \quad W_g = 6h + W \tag{6}$$

The rectangular patch designed at 71 MHz is shown in Figure 1, considering a reduction factor of 8, required to decrease the patch and substrate sizes. The sizes of the patch are given in Table 2 and the feed point location in Table 3. FR-4 was used as substrate; it has a height of 0.0016 m and a dielectric permittivity of 4.2.

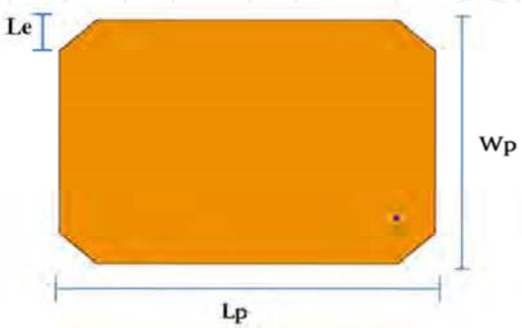


Fig. 1. Single rectangular patch antenna.

The wave group of length λ_g determines to the Length edge (*Le*, in Figure 1) of the cuts. *Le* has a value of $\lambda_g/8$ (see Figure 1), which in this case is of 0.0161184 m. .

With the reduced sizes, the antenna array has been designed using a superposition of two rectangular patches, as it can be seen in Figure 2. Some adjustments in length were required in order to locate both central frequencies of the VHF TV channels transmission, with a minimal error (a shift of 0.14% in 71 MHz and of 0.1% in 195 MHz). As it can be noted, the orthogonal lengths have the same length ($W=L+L1$), as it is desirable for dual polarized antennas (Smith, 2008). The sizes of the rectangular antenna array are given in Table 4.

Patch antenna array sizes (m)	
Wp	0.1272564
Lp	0.1621136

Table 2. Sizes of the individual patch antenna.

Feed point location (m)	
X	0.065
Y	-0.04

Table 3. Feed point location of the individual patch antenna(coordinates are considered as they are established by FEKO program) .

Sizes	W	L	W_1	L_1	W_2
Patch	0.167	0.132	0.017	0.035	0.127
Substrate	0.176	0.142	0.027	0.045	0.1366

Table 4. The rectangular antenna array sizes (in meters).

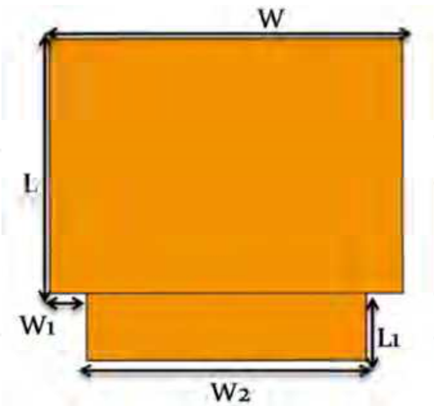


Fig. 2. Geometry of the rectangular patch antenna array.

Cuts on the array were also implemented in order to increase the corresponding gain. The sizes of the array with the cuts implemented on its corner are given in Table 5. The length edge of the cuts is also given by $\lambda_g/8$, as in the case of the single antenna.

Patch antenna array sizes (m)			
Wp	0.16366496	Lp	0.1272564
Wp1	0.01742811	Lp1	0.0165981
Wp2	0.1272564		

Table 5. Sizes of the patch antenna array with cuts.

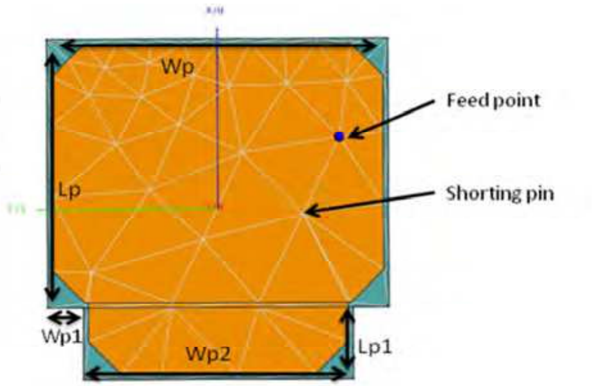


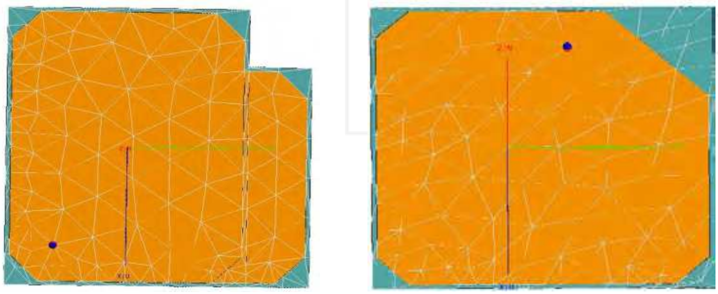
Fig. 3. Geometry of the antenna array (T shape), with cuts on its corners.

The feed point and shorting pin location are shown in Figure 3 and its coordinates in Table 6.

Location, (m).			
Feed point		Shorting pin	
X	0.035	X	-0.0025
Y	-0.0595	Y	-0.04175
Z	0	Z	0

Table 6. The feed point and shorting pin location.

Before to obtain the geometry shown in Figure 3, other two geometries were realized (Figure 4), but there were some problems in each one.



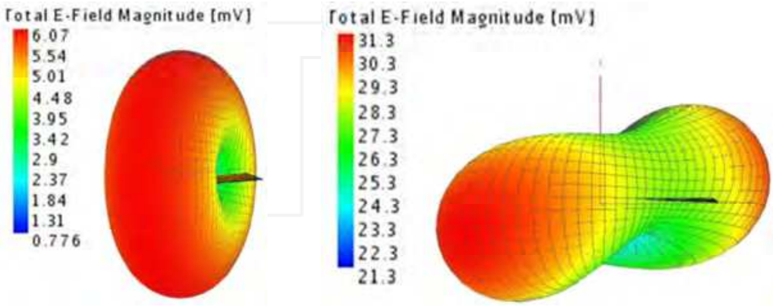
(a) (b)

Fig. 4. First geometries implemented (L shape) and (b) irregular cuts.

For Figure 4(a), the high return loss were obtained (bigger than -5dB), and for (b) the operation frequencies were so far from one to each other. These were the reasons to choose the T geometry to realize the prototype.

3. Simulation results

The 3D far electrical field magnitude patterns as a function of frequency are shown in Figure 5. The electrical far field components, in polar coordinates are shown in Figure 6.



(a) (b)

Fig. 5. Radiation pattern of the far electrical field magnitude at (a) 70.98 MHz and (b) 194.8 MHz.

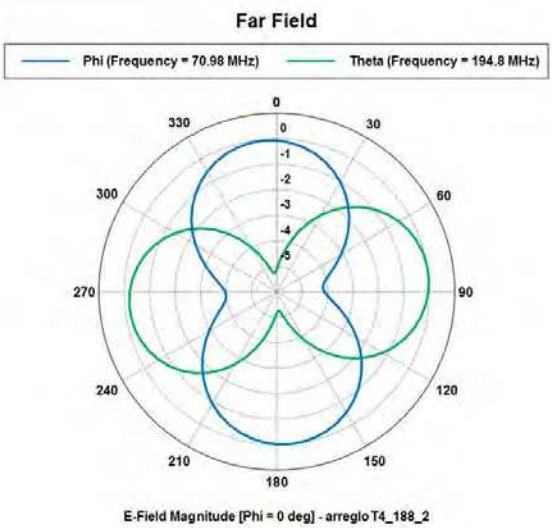


Fig. 6. Components of the electrical Far Field.

As it can be observed from Figure 5a, the radiation pattern at 70.98 MHz, corresponds to an omnidireccional antenna, with horizontal polarization, while in Figure 5b, the radiation pattern at 194.8 MHz corresponds to a directive antenna directed on the X-axis, with maxima on both directions.

The Reflection Coefficient magnitude of the antenna is shown in Figure 7, where the peaks of response are located at 70.98 MHz and 194.8 MHz, very near to the selected design operation frequencies (71 MHz and 195 MHz, which correspond to the central frequencies of the two sub-ranges). A zoom at both frequencies is presented in Figures 8 and 9.

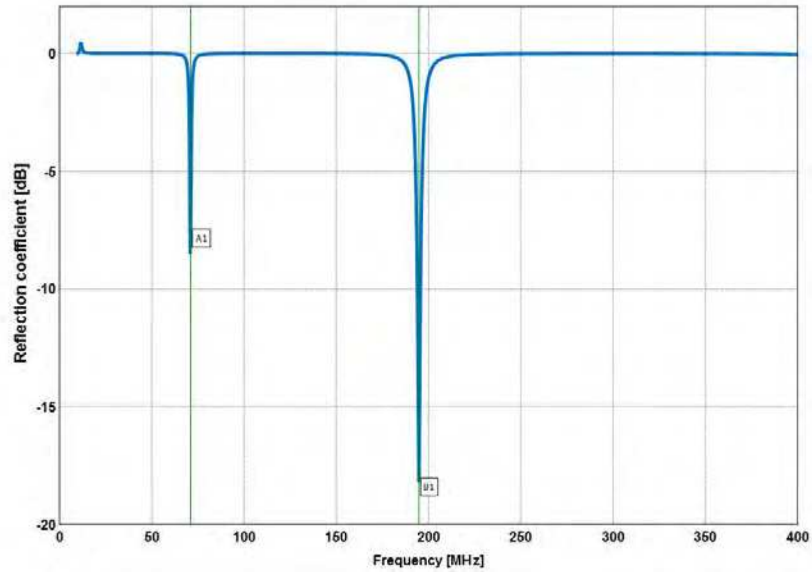


Fig. 7. Reflection coefficient magnitude.

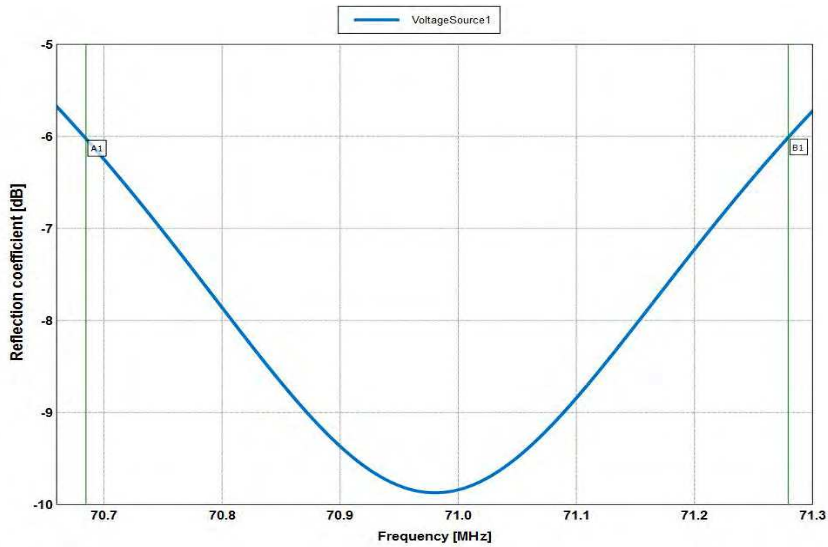


Fig. 8. Reflection coefficient magnitude centered at 70.98 MHz, with a minimum return loss of -9.86 dB.

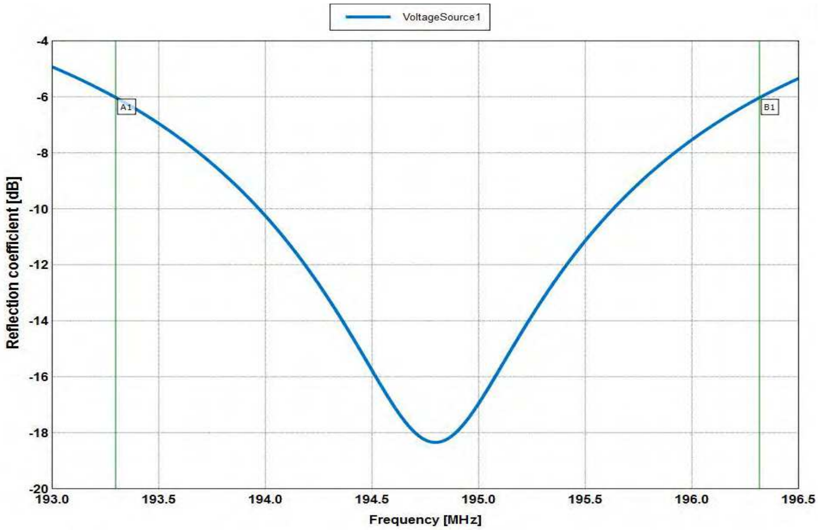


Fig. 9. Reflection coefficient magnitude centered at 194.8 MHz, with a minimum return loss of -18.4 dB.

4. Experimental and practical results

On the base of simulation results, the prototype was fabricated on FR-4 and coupled with coaxial cable of 75 ohms (see Figure 10). In Figure 11, the spectrum analyzer displays the two ranges frequencies received with the prototype: (58.75 MHz, 109.37 MHz) and (155.5MHz, 238.75 MHz), the maximum peak response has a value of -38.5 dBm. Even the primary results shown here, more experimental analysis must be still realized, but it must be recognized that our laboratory equipment is limited.

(a) (b)

Fig. 10. (a) Patch antenna array prototype. (b) Prototype mounted on a PVC base, outdoors of the CIICAp building.

The received range frequencies for the case of a rabbit-ear antenna are shown in Figure 12, where it can be also noted two frequency ranges: (88 Mhz, 108.25 MHz) and (171.25MHz, 182.5 MHz), with a maximum peak of -50 dBm. From these photographs, the bigger

receptions of the patch antenna array are clearly noted, as well as the received power. Even the primary results shown here, more experimental analysis must be still realized.

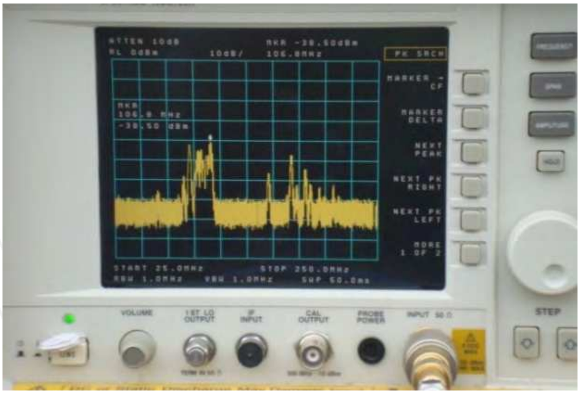


Fig. 11. Two received range frequencies with the spectrum analyzer with the prototype of the antenna array.

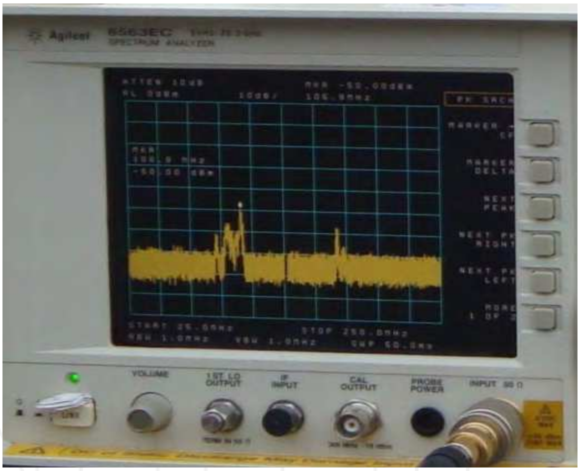


Fig. 12. Two received range frequencies with the spectrum analyzer with a rabbit-ear antenna.

On the other hand, practical tests were also realized on different places of Morelos State. The first ones were realized outside of CIICAp building (18°58'56'' N, 99°14'1.9'' WO), with the antenna located approximately at only 2 meters of the ground. The photographs are shown in Table 7.

Using an analogical TV, a comparison of the reception of the most common channels, considering two commercial antennas (a mini-combined antenna (Figure 13) and a rabbit-ear antenna) and the prototype was also realized.

Reception with the prototype	
	
Channel 5	Channel 9
	
Channel 7	Channel 13
Reception with the commercial combined indoor antenna	
	
Channel 5	Channel 9
	
Channel 7	Channel 13

Reception with the Rabbit-ear antenna	
	
Channel 5	Channel 9
	
Channel 7	Channel 13

Table 7. TV channels reception of openly TV using a scanning TV.

Fig. 13. Mini-combined antenna.

As it can be observed from Table 7, the best reception was achieved with the patch antenna array, followed by the reception with the combined antenna, where some problems were appreciated in channels 5 and 13. The antenna with more reception problems was the rabbit-ear antenna.

On the other side, the antenna prototype was also used on a house roof, in three different places using digital TVs. At first, the tests were realized for a household reception in Temixco, Morelos (located at 18. 51° N, 99°13’48’’ WO, with a height over sea level: 1,280 m). In Table 8, photographs of four analogycal representative channels are shown, with a considerable sharpness in all them. In this place, two High Definition (HD) channels were also received (11 and 13; see table 8).

<table>
<tr><th colspan="2">Reception with the prototype</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Channel 2</td><td>Channel 5</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Channel 7</td><td>Channel 13</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Channel 11 HD</td><td>Channel 13 HD</td></tr>
</table>

Table 8. TV channels reception using a LCD TV.

As second case, other tests were realized considering our prototype and a rabbit-ear antenna for a household reception in Monte Casino (located at 19°00’53.7’’ N, 99°14’50.6’’ WO, height over sea level: 2250 m). With the prototype the reception of the analogical channels was possible without problems, with better sharpness that in the case of the rabbit-ear antenna.

Special attention was focused on signal level of the HD reception of the single channel received there, due to this attribute of the TV. In Tables 9 and 10 the signal intensities are shown for both cases.

TV channel	Current level (%)	Maximum level (%)
13.1	44	48

Table 9. HD reception with a rabbit-ear antenna.

TV channel	Current level (%)	Maximum level (%)
13.1	50	55

Table 10. HD reception with the patch antenna prototype.

When the prototype was used as outdoor antenna, the maximum intensity reception was obtained (see Table 11 and Figure 14).

TV channel	Current level (%)	Maximum level (%)
13.1	59	59

Table 11. HD reception with the patch antenna prototype located on the house's roof.

Fig. 14. Visualized images of HDTV reception antenna using the patch prototype, which is located on the house's roof.

Finally, the third place where the tests were realized was Morelia, Michoacan (19°43' N, 101°12' WO), another Mexican State. The tests were realized using a LCD TV with our prototype and a commercial aerial antenna (Figure 15). The results are shown in Table 12.

From Table 12, it can be observed that the TV reception is better in the case of the prototype not only for the analogical channels, receiving an additional one, but also for the single HD channel received (1.1). It must be noted that the location of both antennas is not the best (Figure 15), but several homes in our country have similar conditions. The sizes of the antenna array prototype are considerable smaller than the available aerial antenna.

Fig. 15. Location of the antennas used on a house roof in Morelia, Mich.

Reception with the prototype	
	
Channel 4	Channel 8
	
Channel 10	Channel 21 (Repetition of channel 10)
	
Channel 39	Channel 45

	
Channel 13	(HD) Channel 1.1
Reception with the commercial aerial antenna	
	
Channel 4	Channel 8
	
Channel 10	Channel 21 (Repetition of channel 10)
	
Channel 39	Channel 45

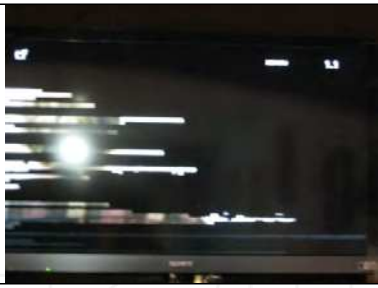
Not available	
Channel 13	(HD) Channel 1.1

Table 12. Visualized images of TV received with antennas located on the house's roof.

5. Conclusions

The simulations of the patch antenna array show its dual frequency performance. In spite of the inherent narrow broadband of the microstrip antennas, the practical reception, realized in different geographical sites of Morelos and in Morelia, Michoacan, has also confirmed the feasibility of its use for household reception of openly TV frequency ranges.

The difference in the TV reception can be attributed to the proximity of the repeaters antennas, and to the elevation conditions. The vegetation is also relevant.

The experimental and practical tests show an acceptable reception of channels in both VHF sub-ranges of frequencies.

In TVs that accounts with graphical signal meter, it was possible to observe that with the antenna on the house's roof, the current signal meter obtained its maximal level, for the case of HD channels, which is certainly a very good practical result, and it constitutes a base to suggest its use as outdoor antenna.

In the three tests realized using digital TVs on different places, it must be mentioned that unfortunately the available TVs have different attributes, but in all cases the better reception was obtained with our prototype. The comparison with aerial antennas was only possible where they were available.

The prototype sizes make it a competitive option compared with some commercial aerial antennas available in the market. Additionally, for the case of digital TVs, it does not require of an amplifier or a rotor, once it was properly directed. For the case of analogical TVs the reception improvement is considerable compared with the options shown here.

As future work, it is planned to design an appropriate radome for protection of the prototype to the weather.

The implementation of geometry modifications is also been considered in order to increment the broadband of the antenna array. Its sizes can be also reduced using another material, but its costs will be incremented.

6. Acknowledgment

The authors wish to thank to EM Software & Systems (USA) Inc., for FEKO license. J. G. Vera-Dimas and J. A. Damián Morales acknowledge financial support from CONACYT

scholarships under grants 270210/219230 and 336781/235572, respectively. R. Vargas-Bernal acknowledges partial financial support from PROMEP.

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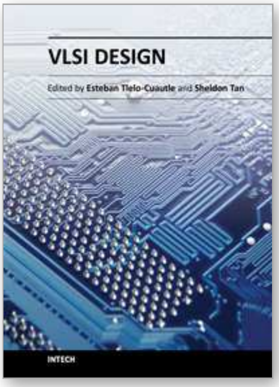
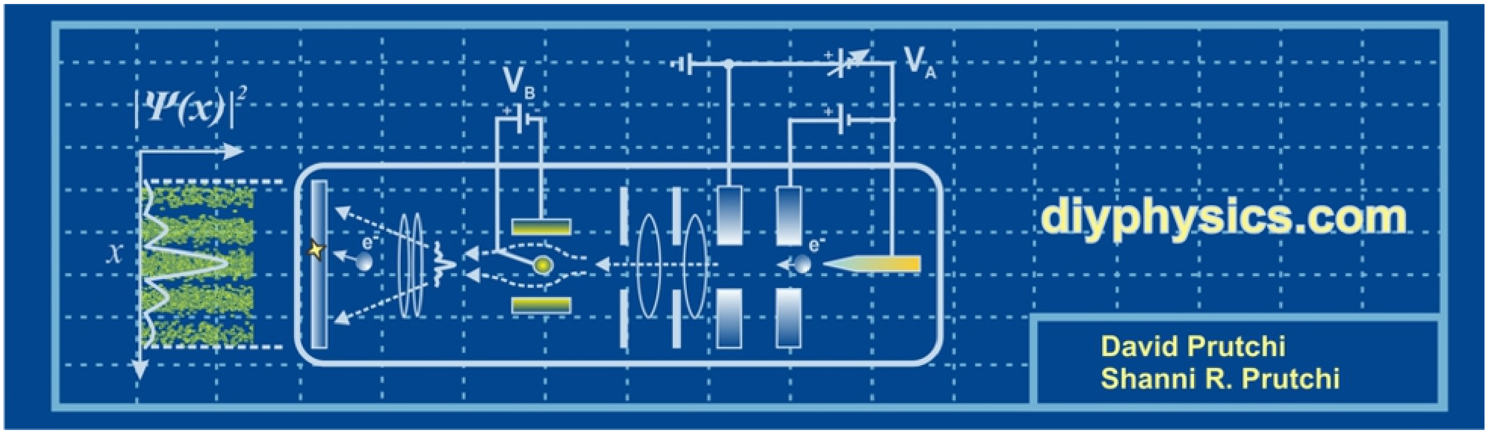


VLSI Design
Edited by Dr. Esteban Tlelo-Cuautle

ISBN 978-953-307-884-7
Hard cover, 290 pages
Publisher InTech
Published online 20, January, 2012
Published in print edition January, 2012

This book provides some recent advances in design nanometer VLSI chips. The selected topics try to present some open problems and challenges with important topics ranging from design tools, new post-silicon devices, GPU-based parallel computing, emerging 3D integration, and antenna design. The book consists of two parts, with chapters such as: VLSI design for multi-sensor smart systems on a chip, Three-dimensional integrated circuits design for thousand-core processors, Parallel symbolic analysis of large analog circuits on GPU platforms, Algorithms for CAD tools VLSI design, A multilevel memetic algorithm for large SAT-encoded problems, etc.



Experimental Modern and Quantum Physics for Do-It-Yourself Science Enthusiasts

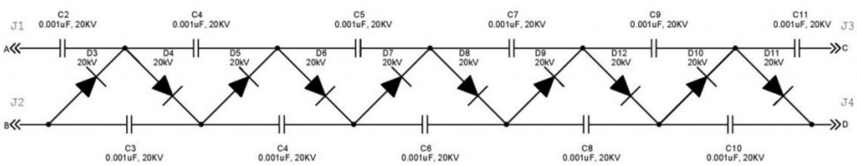
d.i.y. 250 kV High Voltage DC Power Supply with Neat Trick for Switching Polarity

Published on February 9, 2012 by David Prutchi in Chapter 3 - Atoms and Radioactvity, High-Voltage Power Supply

High voltage DC power supplies are used by science enthusiasts for powering electron tubes and x-ray tubes, charging high-voltage capacitors, powering electrostatic “levitators”, etc. Many of these power supplies use a flyback transformer to produce high voltage at high frequency (AC), followed by a “Cockroft-Walton Multiplier (http://en.wikipedia.org/wiki/Cockcroft%E2%80%93Walton_generator)” to rectify and dramatically increase the voltage.

The Cockroft-Walton multiplier uses a cascaded series of diodes and capacitors to generate a high voltage DC potential from an AC input through a circuit topology that uses diodes to charge capacitors in parallel and discharge them in series. The output polarity of the Cockroft-Walton multiplier depends on the way in which its diodes are oriented, so the output polarity (referenced to ground) of a high-voltage DC power supply is usually set during the design.

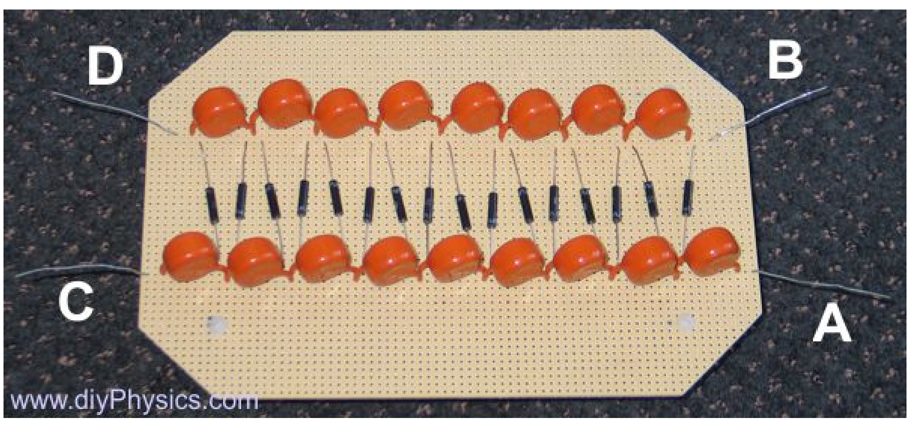
However, since some of our physics experiments require one or the other polarity, we build our Cockroft-Walton multipliers with an extra capacitor so that we can make our HV power supplies output either positive or negative high voltage referenced to ground. The schematic for our “reversible” Cockroft-Walton is shown in the following picture (click to enlarge):



(http://www.diyphysics.com/wp-content/uploads/2012/02/Multiplier_schematic.jpg)

If the high-voltage AC output of the flyback is connected to point “A” of the voltage multiplier, and point “B” is connected to ground, then the output at point “D” will be positive. If however point “C” receives the high-voltage AC, and point “D” is connected to ground, then point “B” will be negative.

As shown in the following pictures, the multiplier should be built on a piece of clean perfboard:



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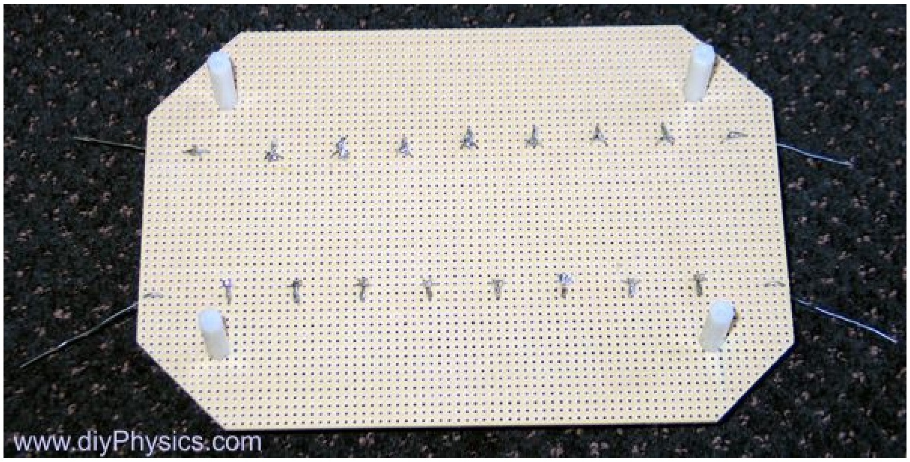
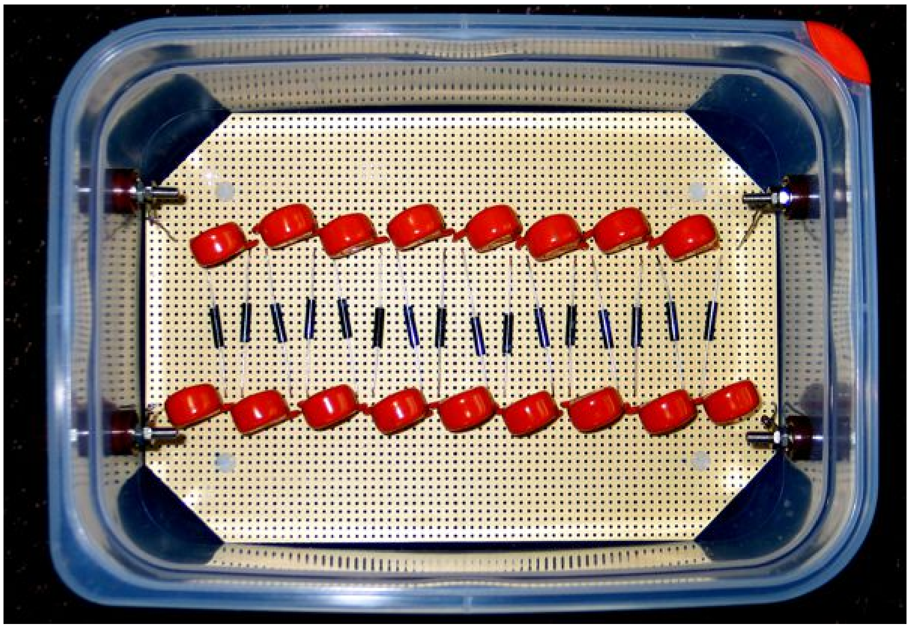
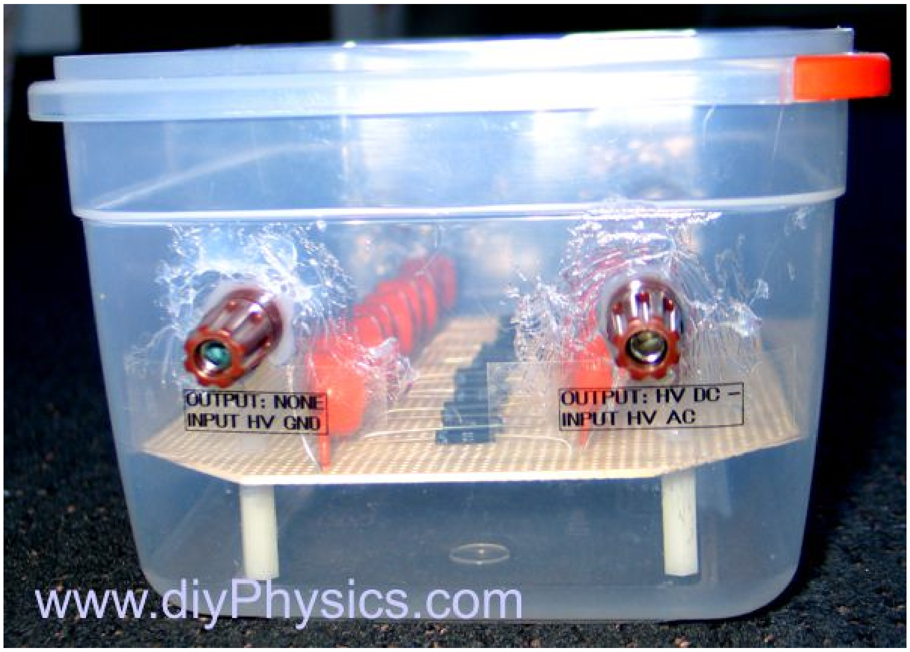


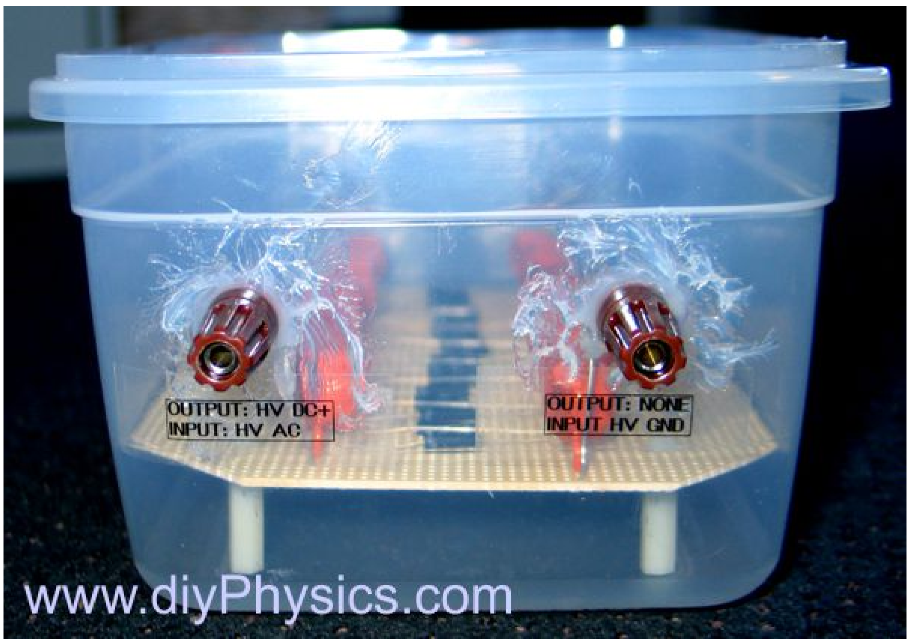
The circuit board is then suspended by nylon spacers inside a plastic enclosure (of the type used to store food):



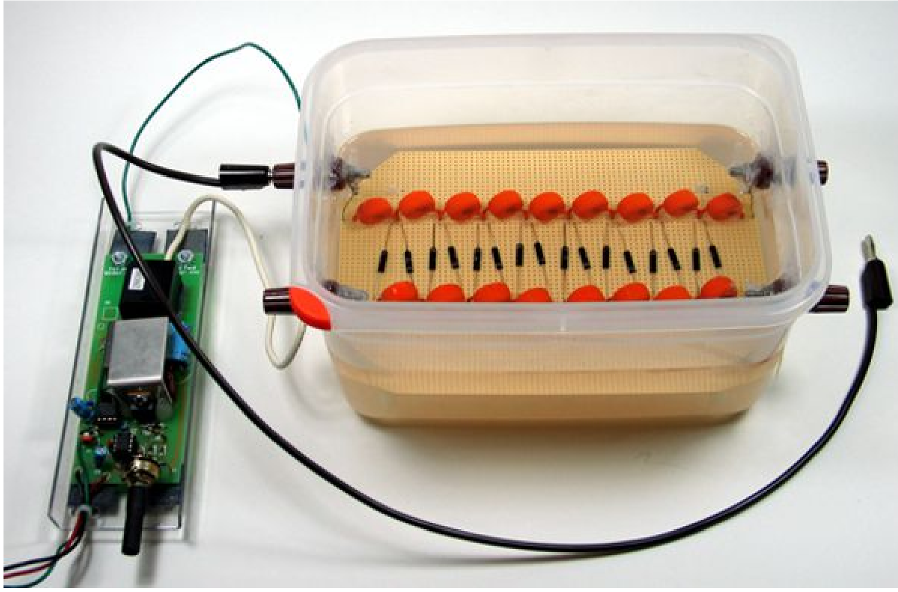
Banana connectors are then installed on the plastic container and wired directly to points A, B, C, and D. The connectors must be sealed very well using silicone RTV:

The connectors are then labeled as follows:

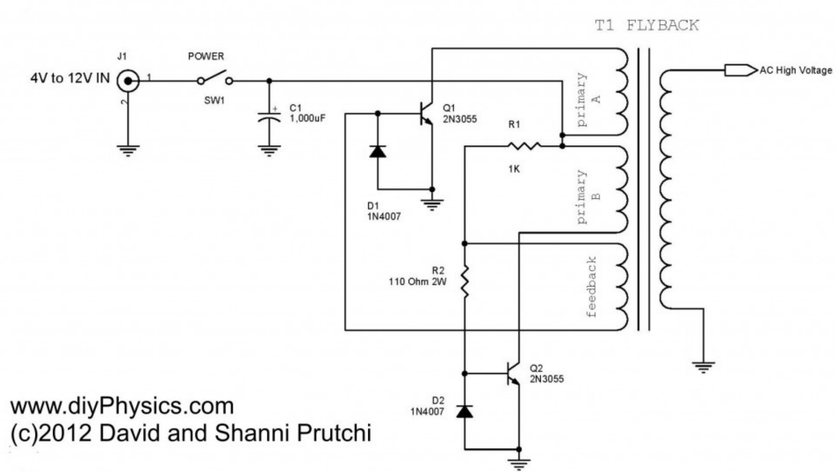




The plastic container should then be filled with pure mineral oil (may be purchased at a pharmacy) to completely submerge the multiplier circuit assembly, which prevents high voltage breakdown between components:



You can use any high-voltage AC power supply to drive the multiplier. Our favorite circuit is the following DC-to-AC inverter (click diagram to enlarge):



(http://www.diyphysics.com/wp-content/uploads/2012/02/HV_AC_Pwr_Supply.jpg)

In this AC power supply, a push-pull oscillator drives a TV flyback transformer from an old color TV (a flyback without embedded tripler). The well-known hack is that the original primary of the flyback is not used. Instead, new primaries are made by winding two sets of four turns each of insulated #18 wire around the exposed core of the flyback transformer. Feedback for the oscillator is obtained through an additional coil of 4 turns of #24 wire wound around the core:

American Journal of Physics
Circuit Cellar
Dr. Enrique Galvez' Correlated-Photon Experiments Guide
Dr. Mark Beck's Undergraduate QM Experiments
The Bell Jar

Equipment Suppliers

Edmund Optics
Excelitas Technologies (Perkin-Elmer)
Images Scientific Instruments
Information Unlimited
quTools
Spectrum Techniques
Sphere Research
Surplus Sales of Nebraska
Surplus Shed
Thorlabs
United Nuclear

Unknown Feed

Physics – spotlighting exceptional research

Synopsis: A Single-Photon Cheshire Cat July 1, 2016
Focus: Biological Cells Form Electric Circuits July 1, 2016
Viewpoint: A Bird's Eye View of Circuit Photons June 30, 2016
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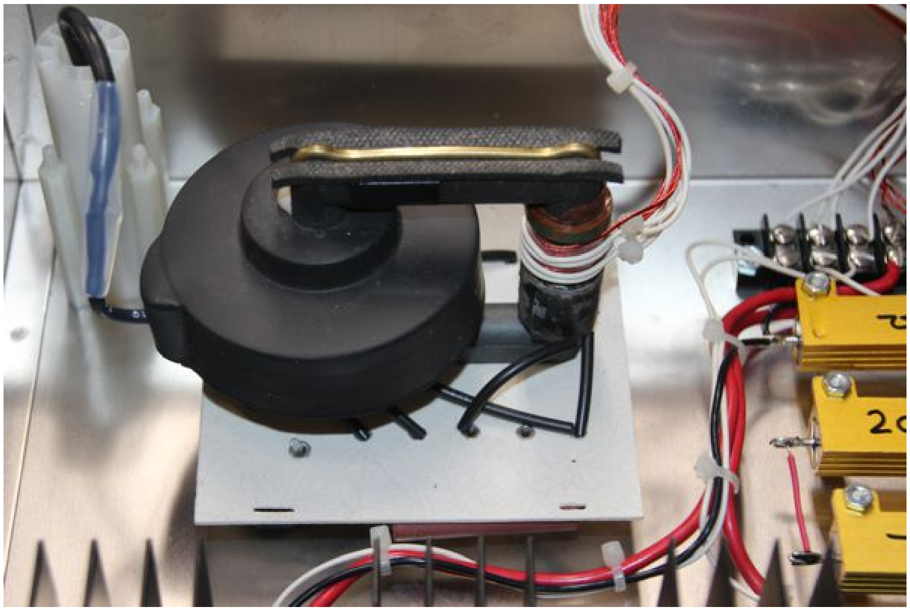
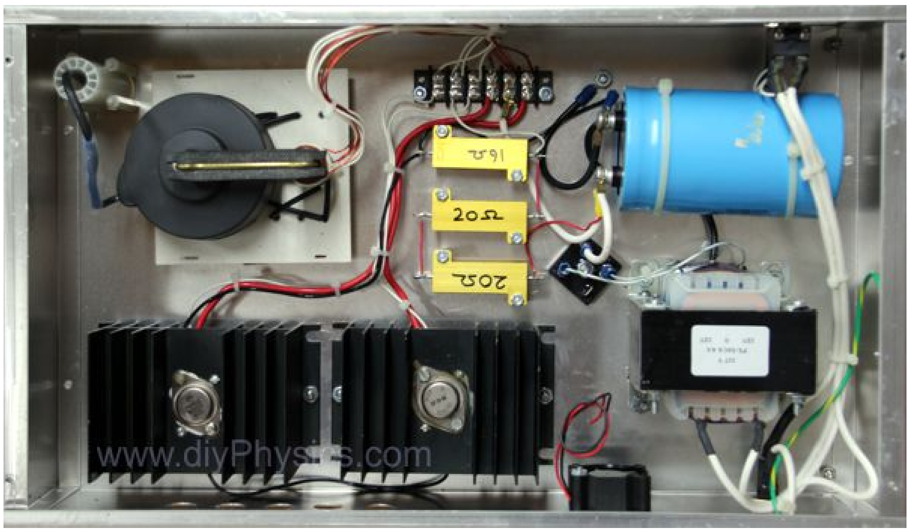
Synopsis: The Little Engine That Could June 28, 2016
Viewpoint: Fermionic Vortices Find their Dual June 27, 2016
Focus: Balls as 3D Gears June 24, 2016
Synopsis: A Relativistic View of a Clumpy Universe June 24, 2016





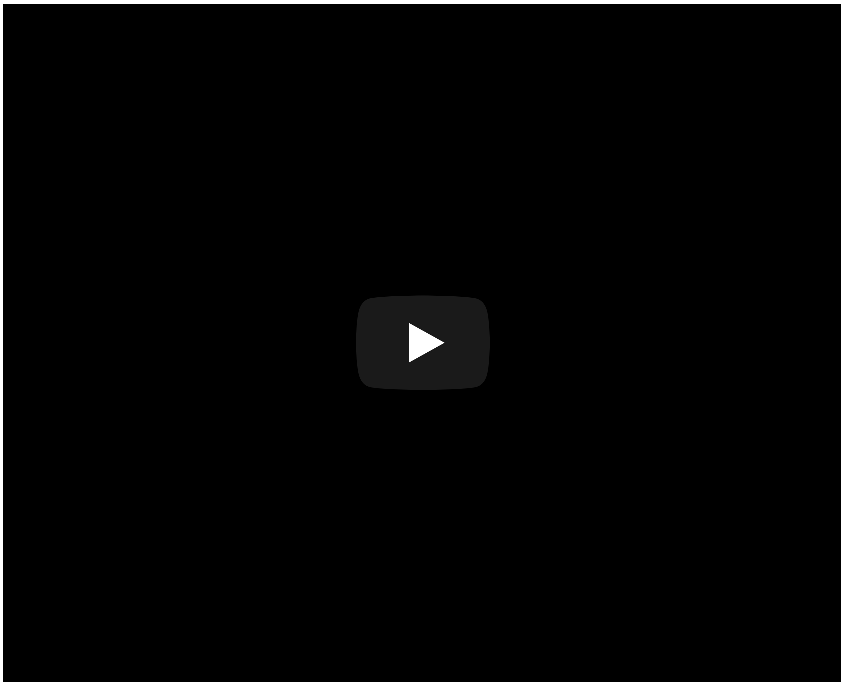
As shown in the picture above, we built the low-voltage DC power supply right into the chassis. We vary the voltage using an external variac (not shown in the pictures). In our power supply, 12 V applied at the input of the flyback driver produces around 250 kV DC at the output of the multiplier. We have measured up to 300 kV DC at higher input voltages, but the corona and breakdown get very scary, so we haven't tried pushing the limit.

> **UPDATE 2/10/2012:** Please see the following two posts for additional information on building the resonant transformer driver, as well as on winding the primary for the flyback transformer:
>
> http://www.diyphysics.com/2012/02/10/universal-resonant-transformer-driver-high-voltage-flyback-driver/ (http://www.diyphysics.com/2012/02/10/universal-resonant-transformer-driver-high-voltage-flyback-driver/)
>
> http://www.diyphysics.com/2012/02/10/adding-your-own-primary-to-high-voltage-flyback-transformer-for-resonant-driving/ (http://www.diyphysics.com/2012/02/10/adding-your-own-primary-to-high-voltage-flyback-transformer-for-resonant-driving/)

The following YouTube video shows an early version of our d.i.y. power supply being used to fly an electrostatic "lifter" that Shanni built many years ago as a grade-school science-fair project:

Feature: Arts & Culture: Feynman for All June 23, 2016
Feature: Meetings: Highlights from DAMOP 2016 June 22, 2016

Unknown Feed

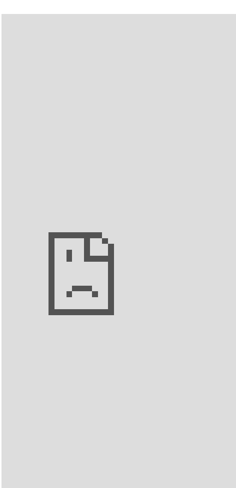


(http://youtu.be/p10OUADRr2M)

In our d.i.y. book "Exploring Quantum Physics Through Hands-On Projects (http://www.amazon.com/dp/1118140664/ref=as_li_tf_til?tag=wwwprutchicom-20&camp=14573&creative=327641&linkCode=as1&creativeASIN=1118140664&adid=0KCMCW3J6G78PZTR0AFH&&ref-refURL=http%3A%2F%2Fwww.diyphysics.com%2F)" we show many ways in which this power supply can be used to perform advanced physics experiments.

DANGER! Please note that this is a dangerous device! It produces high voltages which can cause very painful or lethal electrical shocks. In addition, spark discharges can be produced which can ignite flammable materials or volatile atmospheres. Remember that the capacitors retain charge long after the power supply is switched off. Thoroughly discharge them before touching the high voltage rails!

Please visit www.prutchi.com and www.diyPhysics.com for other cutting-edge d.i.y. projects, and remember to check out our new d.i.y. Quantum Physics book:



14 Responses

Prutchi.com - Posted to www.diyPhysics.com:d.i.y. 250 kV High Voltage DC Power Supply with Neat Trick for Switching Polarity
February 9, 2012 at 12:26 pm

[…] be used to produce either a positive or a negative output referenced to ground. The post is at: http://www.diyphysics.com/2012/02/09/d-i-y-250-kv-high-voltage-dc-power-supply-with-neat-trick-for-s (http://www.diyphysics.com/2012/02/09/d-i-y-250-kv-high-voltage-dc-power-supply-with-neat-trick-for-s)… Cheers, […]

MAKE | How-To: Switchable-Polarity 250,000 Volt Power Supply
February 9, 2012 at 4:01 pm

[…] today's project on diyphysics.com, David Prutchi shows how to build a Cockcroft–Walton multiplier using a "ladder" of […]

250 kV Home Made High Voltage DC Power Supply - Hacked Gadgets – DIY Tech Blog
February 10, 2012 at 6:09 am

[…] you have a project that needs a bit more than 3.3, 5 or 12 volts have a look at this Home Made 250 kV High Voltage DC Power Supply! Of course this isn't your typical supply for the Arduino project sitting on the corner of […]

diy Physics Blog - Universal Resonant Transformer Driver (High-Voltage Flyback Driver)
February 10, 2012 at 10:59 am

[…] use the flyback-driver circuit shown in our d.i.y. 250 kV DC power supply in many other of our setups, so we built a stand-alone universal resonant transformer driver. The […]

diy Physics Blog - Adding Your Own Primary to High-Voltage Flyback Transformer for Resonant Driving
February 10, 2012 at 11:26 am

[…] two prior posts show how to build very high voltage power supplies using flybacks from old color TVs. The advantage of the method we use is that any flyback can be driven, […]

Cockroft-Walton Multiplier can output positive or negative voltage - Hack a Day
February 10, 2012 at 1:03 pm

[…] power supply pool you may be thirsty for a bit more knowledge. Here's a neat illustration of how to build a voltage multiplier that can output a positive or negative supply. It is based on a design known as the Cockroft-Walton Multiplier. It's the add-on housed in […]

diy Physics Blog - Original Source for Flyback Driver Hack?

May 8, 2013 at 9:55 am

[…] http://www.diyphysics.com/2012/02/09/d-i-y-250-kv-high-voltage-dc-power-supply-with-neat-trick-for-s (http://www.diyphysics.com/2012/02/09/d-i-y-250-kv-high-voltage-dc-power-supply-with-neat-trick-for-s)… […]

Hypatia's Protégé

August 16, 2014 at 10:16 pm

Two suggestions:

1) Regarding the Royer oscillator: Instead of 1N4007s you may wish to consider 'fast recovery' diodes…

2) Regarding the Cockcroft-Walton cascade: Please note that the stress on the rectifiers is twice the peak excitation EMF — Hence, with the rectifiers specified at 20KV (as shown), the maximum input to the cascade should not exceed 10KV Peak (7.07KV RMS) — Corresponding to (Max) DC outputs or 99KV (as per the 5 stage cascade shown in the diagram) and 158KV (as per the 8 stage cascade shown in the pictorial).
At the stated 250KV output, each diode is 'seeing' approximately 29KV… Depending on the manufacturer's 'safety margin' this may pose a significant reliability issue…

With constructive intent

Best regards
HP

Jacob Shin

March 15, 2015 at 8:16 pm

What is the output (in kV) of the AC flyback power supply circuit that goes into the input of the Cockcroft-Walton Multiplier Cascade?

David Prutchi

March 16, 2015 at 6:44 am

It depends on the flyback and input voltage, but an old color TV flyback can put out between 25 kV to 35 kV at high frequency to feed the CW multiplier. I get around 300 kVDC out with a ten-stage multiplier.

Thomas

March 21, 2015 at 1:57 pm

Is the 10 stage multiplier the one shown in your photos here?

Thomas

March 19, 2015 at 3:47 pm

A quick few questions.
Your schematic is very nice. Thank you very much for your time, sirs.

1. Are those 1N4007 diodes connected between the BASES and EMITTERS of each transistor? If so, is their purpose to protect the transistors and the rest of the power supply from high voltage kickback?

(I'm only asking because on other flyback driver circuits that use a single transistor that I have seen, the diode employed for protective purposes is placed between the COLLECTOR and EMITTER, not the BASE and EMITTTER.)

Source: http://www.instructables.com/id/2n3055-flyback-transformer-driver-for-beginners/?ALLSTEPS (http://www.instructables.com/id/2n3055-flyback-transformer-driver-for-beginners/?ALLSTEPS)

---

2. What is the kind of wire you are using for the primaries and feedback coil, and what is its topography? (Litz wire? Would single-core enamelled magnet wire suffice?)

What I mean by 'topography' is as follows:

Am I correct in assuming that each coil consists of 4 turns of wire for the first primary, and 4 turns of wire for the second primary, and then 4 turns of the smaller wire for the feedback?

Lastly, is the feedback coil literally wound around ON TOP of the existing primary coils? Or are all three coils wound in descending order if you will, around the exposed core? (Thereby not sandwiched on top of each other?) What would be the differences in performance/functionality of the flyback between one of these winding styles VS the other? Why double-stack the feedback winding on top of the primaries like that… or don't?

Thank you, and warm regards.

Thomas

March 20, 2015 at 1:51 pm

Oh, also, at what minimum frequency is this circuit expected to oscillate at, providing the flyback to be used is not the new style, but one of the large old style devices with the disc shaped, fat secondary?

I am hoping for something over 5 kHz, if this can be determined.

Thanks again.

Thomas

March 23, 2015 at 2:01 pm

Anyone's responses are welcomed at this point, just to gain clarity on how this works. I welcome the discussion.

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Simple demonstration to explore the radio waves generated by a mobile phone.

Dr Jonathan Hare, Sussex University, Department of Physics, Falmer, Brighton. BN1 9QH
Note: this article has been published: Simple demonstration to explore the radio waves generated by a mobile phone J P Hare, 2010, Journal of Physics Education, Institute of Physics, 45, p. 481 45 481

Also see the brief full article at: mobile phone detector

IMPORTANT NOTE: this device works very well on the old style mobile phones (as shown in the photo above). However, it does not always work well with modern smart phones. This may be because modern phones use higher frequencies, less power and use the power in a slightly different way (e.g. spread spectrum). Some smart phones do work and success may be due to the signal strength of the local mobile phone mast nearby. If you are in a low signal area the phone will create more power to ensure reliable communications. If you are in a very strong signal area (very near the local network) your phone will drop its output power and consiquently there will be less power to pick-up and to convert to a voltage to light the LED.

Described is a simple low cost home-made device that converts the radio wave energy from a mobile phone signal into electricity to light an LED. No battery or complex circuitry is required. The device can form the basis of a range of interesting experiments on the physics and technology of our mobile phones.

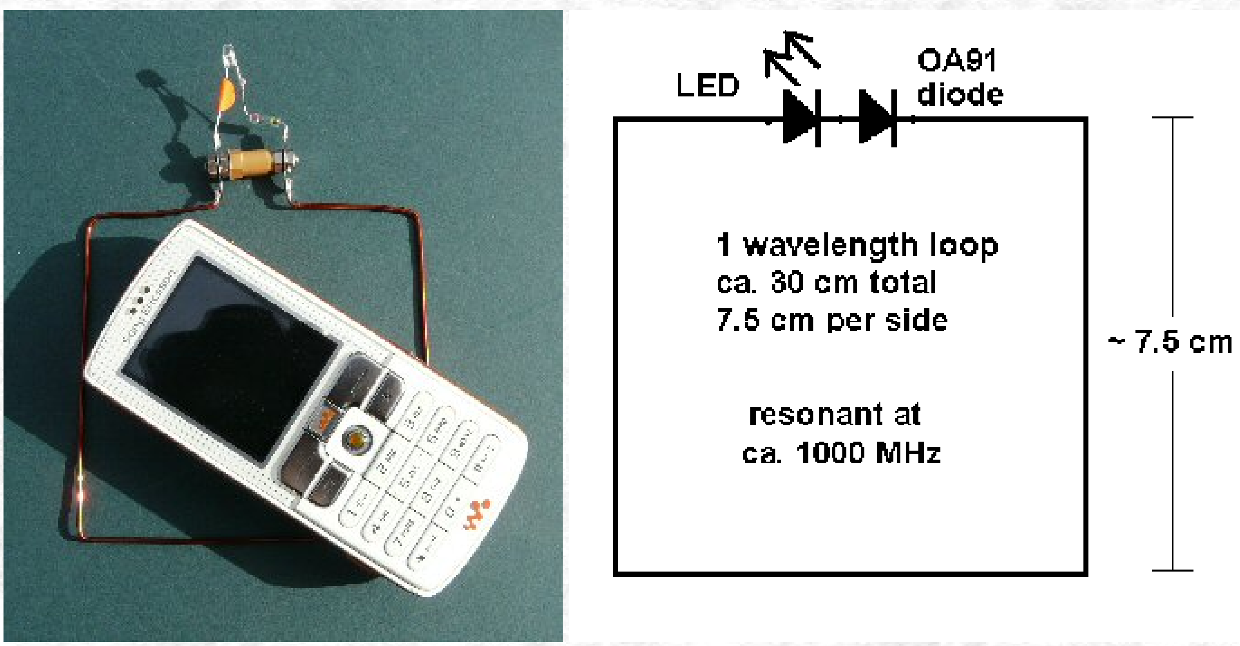


Fig. 1: left: mobile phone radio wave detector and right: the simple schematic

Introduction

Electromagnetic radiation (EMR) is at the heart of modern mobile phone data communications networks. The way a mobile phone and local base stations (the antenna covered masts you see dotted all around the place) communicate between each other is by using EMR in the radio wave part of the spectrum [1,2,3]. On switch-on your mobile sends digital information pulses by rapidly switching on and off the radio waves rather like a fast Morse code signal. Your text or voice is also converted into a series of digital pulses and sent across the network to be decoded (reassembled) by another mobile phone you dialled.

EM radiation and radio waves

Mobiles make use of various bands of radio frequencies to communicate between the mobile to base and the base to mobile: in Europe these include 900 and 1800 MHz (850 and 1900 MHz in the USA and Canada) [2, 3].

The relationship between wavelength, speed of light and the frequency follows the well known formula:

Wavelength λ (m) = speed / frequency = c (ms^{-1}) / ν (Hz)
λ (m) = 300,000,000 / ν (Hz) or approximately:
λ (m) = 300 / ν (MHz) ..... Equation 1.

So for a mid-range of about 1000 MHz (1 GHz) we get a typical mobile phone wavelength of about:
λ = 300/ 1000 = 0.3 m = 30 cm.

Simple radio wave detector

The loop consists of about a wavelength of wire, ca. 30 cm so each side is about 30/4 = 7.5 cm. The dimensions are not critical. The two ends are connected directly to a simple series circuit consisting of a high brightness LED and a germanium diode. They need to be connected correctly. All these components are cheap and readily available from electronic stores [4]. The loop can be made from a piece of copper wire roughly bent into a square (although a circular loop or rectangle will also work). If the wire is insulated remember to scrap off the insulation and solder-tin the ends. Simply solder the germanium diode and LED into circuit as shown in the diagram.

On a new LED the long lead is the positive (anode) while the short lead is the negative (cathode). The germanium diode has a line (band) around the end which is the cathode. When correctly wired the LED and the germanium diodes are connected so they both allow current to pass in the same direction, i.e. in the circuit diagram the arrows point in the same direction. In practice this means the LED and germanium diode are joined at the cathode of one and the anode of the other.

In my prototypes I used an insulator between the loop ends (light coloured cylinder in the photo) to make the whole thing more sturdy but this was purely for mechanical reasons and is not needed for the circuit to function properly. Note: a much more sensitive version using a x10 and x100 DC amplifier is described on my web site [6].

How it works and how to use it

When a radio wave passes across a metal object the EM fields cause the charged electrons in the metal to oscillate and this causes small AC currents at the same frequency to be induced into the metal. If a mobile is brought near to the loop and a call or text is made [5] the radio waves emitted from the phone pass across the loop. This induces a voltage into the antenna (the loop) and if it is close enough will be large enough to light the LED. As the loop is about one wavelength in size it is resonant and so there is a good transfer of power (low reactance) between the radio wave and LED.

The mobile phone automatically tests the network and adjusts its transmission power to maximise the battery life and minimise network interference. As a result the brightness of the LED will depend on the data being sent (the average signal), the local signal strength and how close the loop is to the phone. Why the second diode? - It's curious why the germanium diode is needed at all. The LED is a Light Emitting Diode after all and one would not think that another diode would help. However my initial experiments failed because I had not included it. The LED will have a relatively high capacitance which at these frequencies will tend to de-tune the loop and short out the LED. The germanium diode however is made up of a tiny wire which only makes a point-of-contact onto a piece of semiconducting germanium so it's 'self' capacitance is very low keeping the loop resonant.

The germanium diode will rectify the AC signal from the loop forming a series of DC pulses that will be nicely smoothed by the LED's capacitance. Without the diode however the raw AC signal from the loop will tend to be averaged to zero by the LED's capacitance.

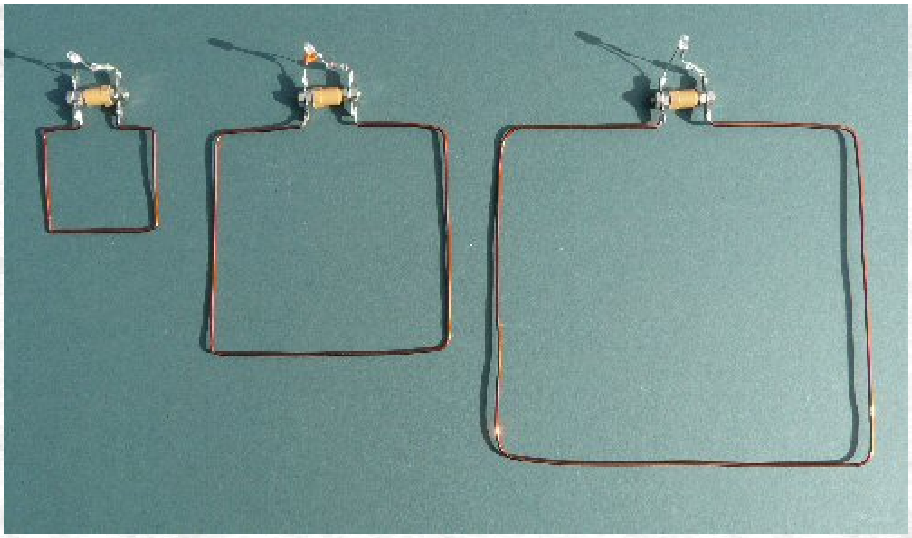


Fig. 2: Three loops in a row of varying size. The one described here and shown in Fig. 1 is shown in the middle. Smaller ones may well work better for higher frequencies such as the 3G networks (see below).

Other size loops
Fig. 2 shows a set of three loop devices with edge lengths of roughly 3.7, 7.5 and 15 cm. You can find out for yourself that the best match to the mobile signal is with the full wave loop of ca. 7.5cm per side. The other loops do work to varying degrees however (smaller ones may work better for the 3G network). The larger loop works well for the '70 cm' amateur radio bands.

Polarisation
The electric and magnetic fields making up the EM wave are orthogonal (they are at right angles to each other as they pass through space) to each other but depending how they are generated by the transmitting antenna can arrange themselves in any orientation with respect to the ground. If the electric field is parallel with the ground we say the wave is 'horizontally polarised' while if its normal to the ground we say its 'vertically polarised'. The loop antenna will respond best to one type of polarisation (depending on its orientation) so it's worth experimenting with the orientation of the mobile (or the loop) to get the strongest signal - brightest LED.

Mobile antenna
Inside your mobile phone is a transmitter / receiver and antenna. Many mobiles have this antenna at the top of the phone but some of the PDA type phones have it at the bottom. As a result you can locate the position of the antenna by moving it around the center of the loop till you get maximum LED brightness.

Networks
There are various different networks that a mobile may use both in the UK and abroad. It may be that you need to adjust the network phone settings on your mobile i.e. change from "automatic select" to set for "GSM" so as it get the strongest signal to light the LED. Note: the 3G network might not be powerful enough to light the LED. As the GMS network is currently the main network over the UK the device should work anywhere where you can get a signal as long as you check the correct selection on your mobile menus [5, 7]. The 3G network operates on a higher frequency (smaller wavelength) so you might find a smaller loop will work better than the main one described here. See 'other experiments' section below.

Test signals
In order to pick up the radio wave energy from the phone it obviously needs to be transmitting a signal. There are a few ways to do this:

1) On switch 'on' (or change of network) you can see that the mobile initially transmits for a few seconds to the network to tell it it's there (especially if you have moved since turning it off). You don't actually need to dial a number to detect these signals.
2) Even if don't text or call, throughout the day the mobile will send out data to 'keep up' with the network, especially if you are moving around (going through train tunnels etc. see below).

3) When you make a phone call you will transmit. Initially there is quite a lot of data being sent but in a few seconds data / power only gets transmitted when you speak. So to light the LED continuously you need to talk or provide some background sound continuously. Your service provider voicemail might be a good free phone number to try for these experiments [5].

4) Texting is the easiest way to show the radio wave power being transmitted. Long texts will light the LED for longer than short texts.

5) Finally set up the mobile on the loop and use another phone to text or phone the mobile. Even though you are not directly using the phone you will see that even on 'receive' the mobile phone transmits data to and fro. Ring off before you get charged.

Note: If you can use a free phone number it will save you money [5].

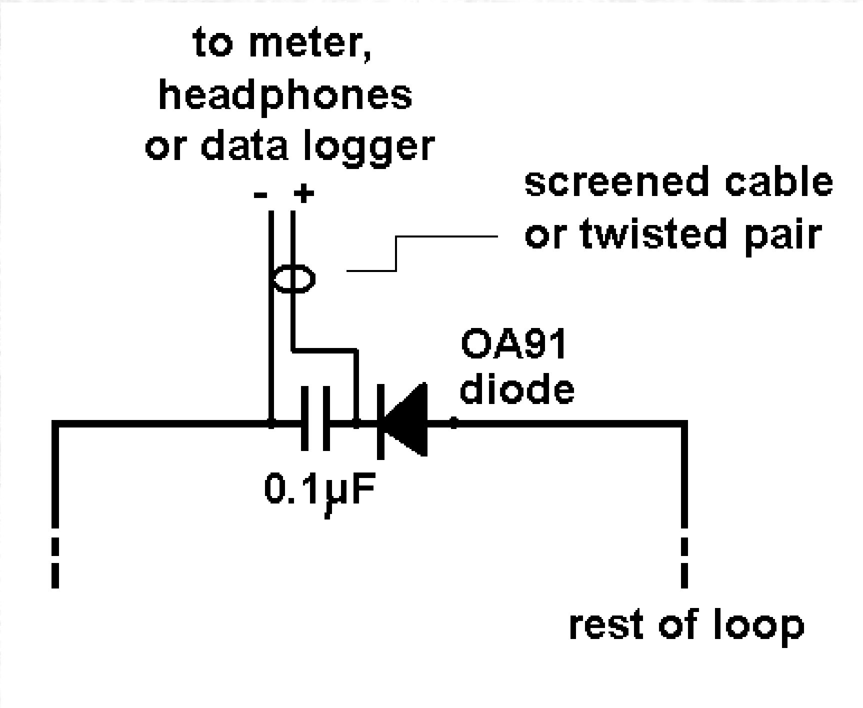


Fig. 3: Adding a capacitor and coax (or twin) lead so that headphones, a meter or a data logger can be connected (Note: diode is reverse wired compared to Fig. 1).

Other experiments:
Hearing data - if headphones are wired across the LED they will convert the voltages into sound and you can 'hear' the clicks of the digital data being transmitted. These are the same clicks that so easily get picked up by sensitive electronics such as a stereo amp or recording equipment when making a video for example. Hence - 'no phones on' when filming.

Logging data - if a meter, or better still a stand-alone data logger, is attached across the LED then one can monitor the EMR from the phone. For example even if you are not making a call your mobile will send signals too (and receive signals from) the network while travelling around. Fig. 3 shows a simple modification using a de-coupling capacitor so that a coax cable (or twisted pair) can be used to go to headphones, meter or data logger. Note the diode has been reversed so that the logger has the correct + and – connections for a unipolar input logger. The capacitor should help average the signal and stop radio frequencies going down to the logger. If one is available a few turns of the wire can be wound within a ferrite ring near to the logger so that maximum immunity to the mobile phone signal can be obtained for the logger electronics.

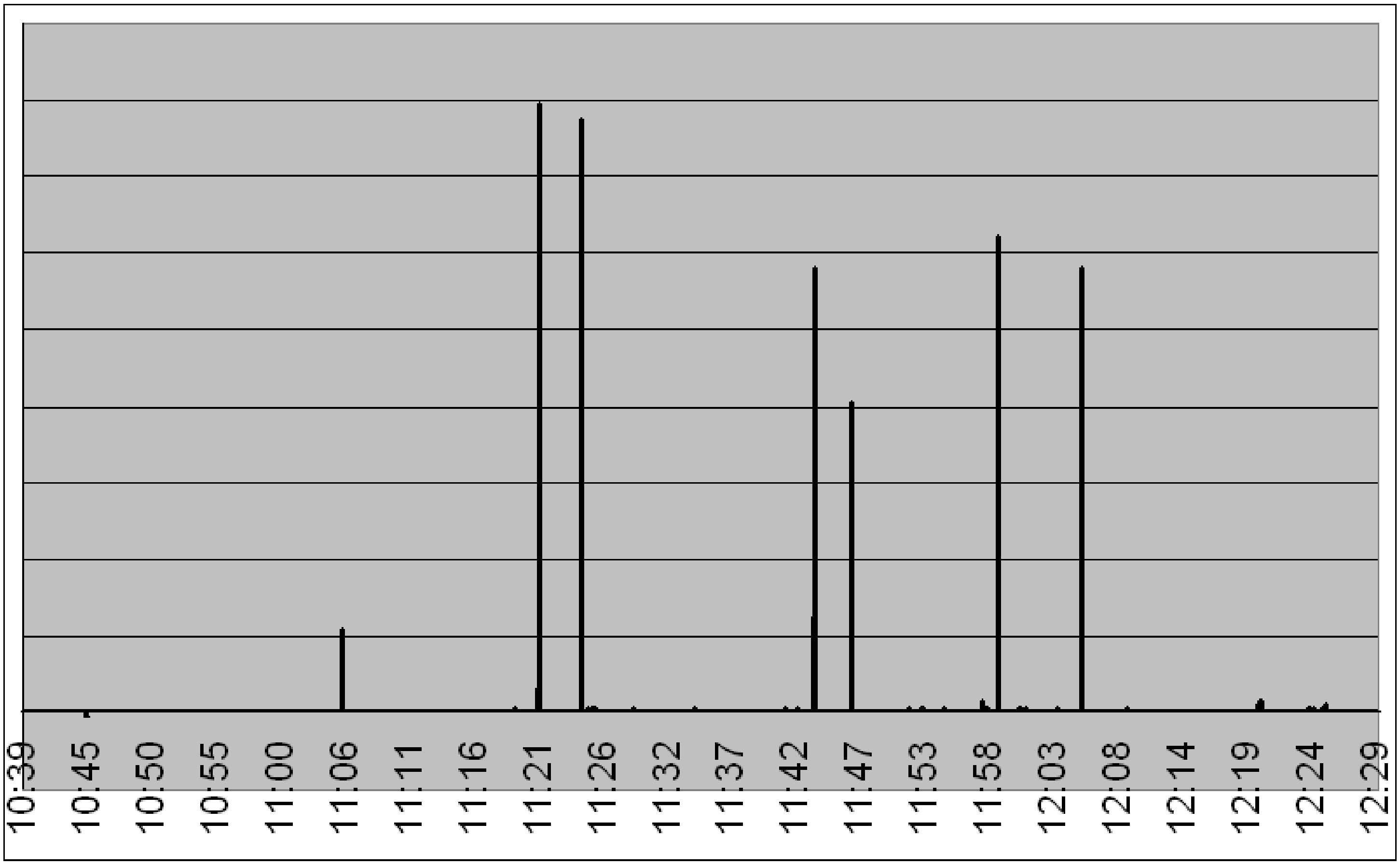


Fig. 4: Typical mobile phone data signals sent out onto the network while travelling around. These were recorded by a data logger from a mobile using the loop (no calls or text were made) while travelling on the train from Brighton to London Victoria (and then around London and return). Many of these peaks were the phone sending out 'I am here' data after coming out of one of the many long tunnels under the South Downs during the journey.

Out and about - Once you can log data you can discover all sorts of interesting things your mobile phone is doing without you realising it. Fig. 4 shows the plot over a few hours of travelling between Brighton and London (and within London) on the train. The detector was simply placed near to a phone that was not making or receiving a phone call or text, but was turned on.

The graph shows that the mobile sends out signals to tell the network where it is as it travels along and in particular goes in and out of long train tunnels. The peak heights vary because of the different powers the mobile transmits at depending on the signal strength of the local network and also because of the way the data logger 'snatches' a reading from the circuit every few seconds. As your phone sends out data onto the network to ensure the very best communications as you move around, so your mobile and the network obviously knows where you are and where you have been. Thieves and criminals beware the police can track you!

The inverse square law - If the transmitting mobile phone is moved away from the loop one would expect the signal to drop off. Unfortunately because both diodes need a certain threshold before they conduct the detector is not sensitive to small signals and not very linear. Therefore it's not very easy to use the device to measure the inverse square law (drop in signal v distance away) but of course you can see the signal go down. You could perhaps use the device to plot isobars - i.e. plot the equal intensity signals around the phone / nearby objects.

Changing the resonant frequency of the loop - you might be able to make some simple sliding mechanism (e.g. a small trombone-like mechanism) out of metal tube for example to tune the loop device for different frequencies. Then you can use it to find the average wavelength and so determine the center frequency by adjusting the size for maximum brightness of the LED. The wavelength can be determined by measuring the total distance around the loop. If we assume the antenna is one wavelength in total length then the frequency can be established by rearranging Equation 1, i.e. ν (MHz) = 30,000 / L (cm), where L is the length around the loop (cm).

Note: You will need to allow the transmitted digital signal to 'settle down' i.e. make measurements only after a few seconds after dialling / pick up so that only the sound data is being transmitted rather than the initial connection data. A constant sound will also need to be made so that the mobile phone continuously transmits data. It's worth playing music near to the phone or constantly whistling to keep sound coming into the phones microphone.

Mobile phone detector - teachers who want to know if the students / pupils really have turned-off their mobile phones (rather than just put on 'silent') can wire the loop device into the class room white-board speakers. Any mobile that is on in the class will send out signals which (if you are close enough) you will hear the data going to and fro - you will have your very own 'who's got their mobiles on' device which might be useful for exams etc.

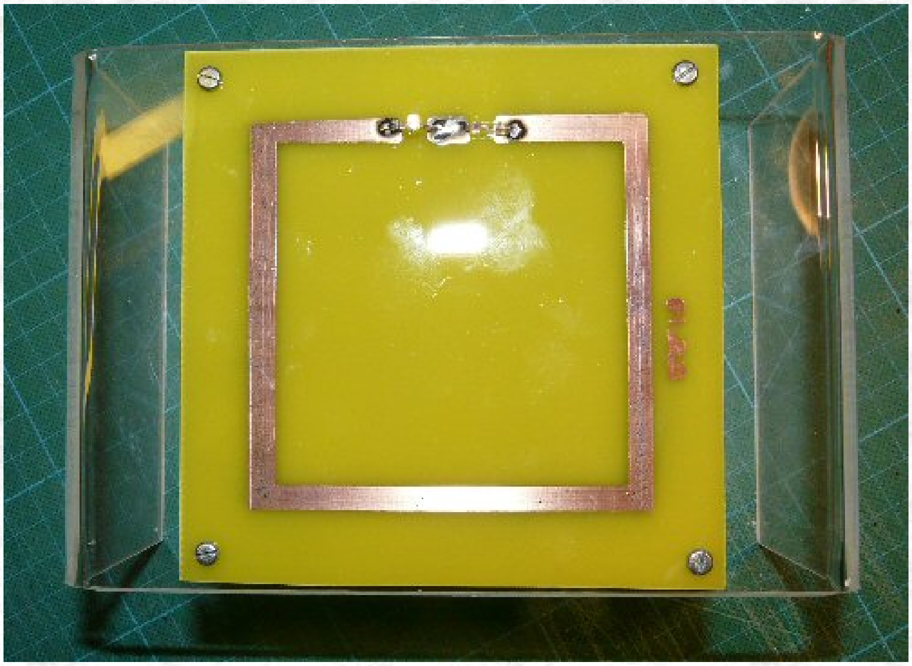
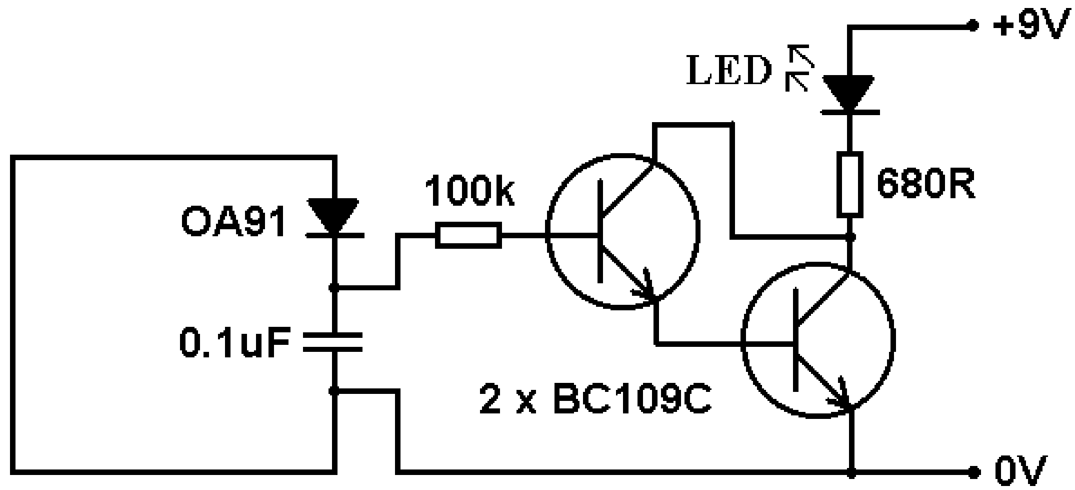


Fig. 5: The SEPNet 'deluxe' printed circuit board version (pcb) on a perspex stand where the loop is composed of a pcb copper track and the diode and LED soldered onto the board (top) [8,9].

Summary
All in all then, for such a simple easy to make device I hope you agree that there is a lot of scope for interesting science / technology investigations with your mobile phone. The device would make a good science week project (for radio amateur clubs etc.) A 'deluxe' pcb version (Fig. 5) on a perspex display case (Fig. 5) is currently going around the southern UK as part of the SEPnet outreach work, see the 'Radiation Exhibition' [8] and also as part of my on-going lecture series [9].

Post publication additions
(What follows was not included in the published article as this calculation was worked out later). A full wave loop is resonant and so looks purely resistive to the radio waves. Such a loop will have a resistance of about 100 ohms (Note: this is the AC resistance and not the DC resistance which will be very low). Now power P = V x I (V = voltage and I = current) and resistance = R = V/ I therefore $P = V^2 / R$ or rearranging $V = \sqrt{(P \times R)}$ which means that the voltage created by a power level of say 50mW (say for argument that roughly half the mobile phone power) arriving at the antenna will be about $V = \sqrt{(100 \times .05)}$ which is aprox. V = 2V, enough to light an LED.



This circuit uses a two transistor darlington driver to amplify the signal from the loop and diode making the detector much more sensitive. The LED will be much brighter using this circuit. Note: the circuit needs a battery to power it (e.g. a PP3 9V)

References

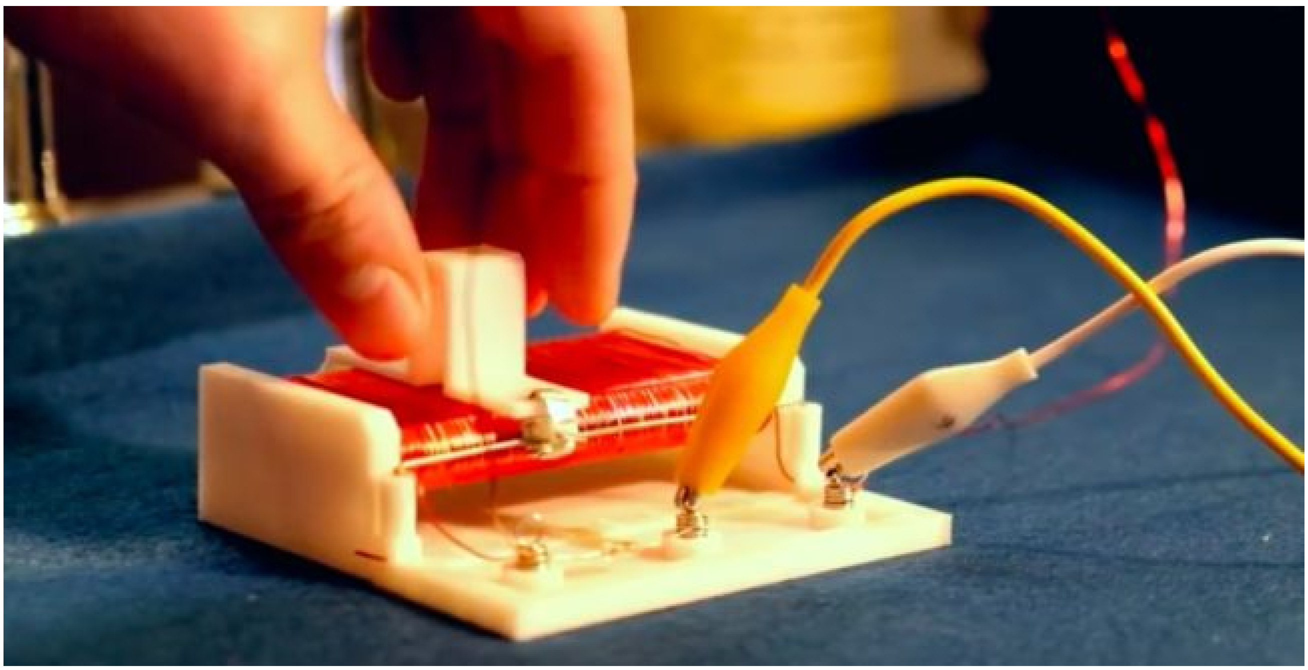
[1] These ultra high frequencies (UHF, > 1000 MHz) are also often called microwaves.
[2] wiki pages
[3] Elektor Electronics magazine, June 2005
[4] order codes for the germanium diode and LED are:
e.g. Germanium diode: Maplin Electronics: QH71N, Rapid Electronics: 47-3114
e.g. LED: Maplin Electronics: UF72P , Rapid Electronics: 55-0085
[5] to save money use your voice mail service (often you simply dial 121).
[6] for details of an amplified detector see: wavemeter
[7] select 'network setting' from the mobile phone 'settings' menu and then go to 'network mode' and select 'GSM 900/1800' rather than 'automatic'.
[8] SEPnet mobile phone device on display throughout southern UK. [9] for details of my talks see: talks and workshops

THE CREATIVE SCIENCE CENTRE

Dr Jonathan Hare, Brighton, East Sussex. BN1 9QJ.

TAG ARCHIVES: CRYSTAL RADIO

Make your own 3-D printed crystal radio

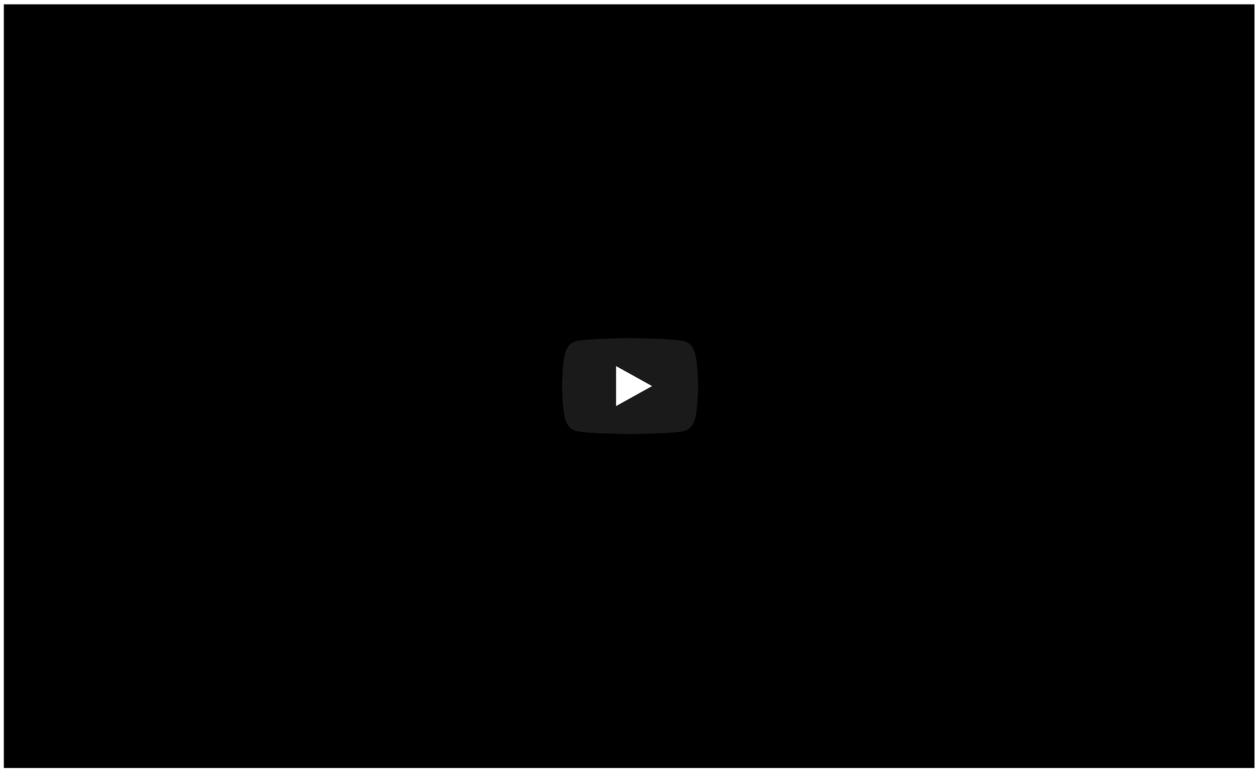


(Source: Southgate ARC)

> *Did you know you can build your very own working 3D-printed radio – without any soldering, electronics experience, electric cord, or even batteries?*
>
> *Digital Trends reports that's exactly what talented Houston, Texas-based 3D-printing and electronics enthusiast Sage Hansen has created. And he's willing to show you how to do it, too.*
>
> *Called a crystal radio receiver, or sometimes a "cat's whisker receiver," this is an incredibly simple type of radio receiver that was popular in the earliest days of radio. The only power it requires to work is the received radio signal, which is used to produce sound. It is named after its most important component, the crystal detector or diode.*

"AM radio was one of the first ways of transmitting audio to a very broad audience in the early 1900s, but it is still very popular today," Hansen told Digital Trends. "It starts with the radio station converting their audio sound waves into electromagnetic waves, which can travel great distances.

Each radio station uses a specific frequency that is constant, but the sound waves are mixed so they amplify and modulate the base radio wave. What makes the crystal radio so exciting is how simple the circuit is, and how it can be made out of normal household items.



Watch the video and read the full story at https://www.digitaltrends.com/cool-tech/3d-printed-working-radio/

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This entry was posted in How To, News, Radios and tagged Crystal Radio, Southgate ARC on January 14, 2018 [https://swling.com/blog/2018/01/make-your-own-3-d-printed-crystal-radio/] by Thomas.

Radio Caroline and a crystal radio: "The making of a rebel"

Radio Caroline circa 1960's.

Many thanks to *SWLing Post* reader Mike, who shares a link to this story from the blog République No.6:

> ***Growing up in Piennes Lorraine, Radio Caroline the making of a rebel***
>
> *[A]t night with my younger brother we would listen to a "pirate radio station" on a boat that would put real good music on, crusing the international waters between England and France. He burst in laughter and told me: That's Radio Caroline". That was it. My brother and I would listen to that station nearly every night on an old "galena radio receiver" with a huge antenna hidden in the attic built with copper wire we stole at the mine. I mean we didn't really steal it, it was everywhere. It was the wires used by miners to connect detonators to batteries when blowing new tunnels and locals were using it for all sorts of things, like holding parts in chicken coop to tie tomato or green bean plants to stakes and could be found everywhere.*
>
> *Actually at first we set the antenna in our bedroom but somehow it wasn't long enough not to mention mom who saw it and tore it down giving her an other excuse to punish us. So we decide it to place it in the attic where no one ever went.*
>
> *The most difficult part was going to the attic, there wasn't any stairs. We had to bring a ladder to the trap leading to it. Mom was watching us like a hawk, looking for any excuses to punish us.[…]*
>
> *Read the full story at République No.6.*

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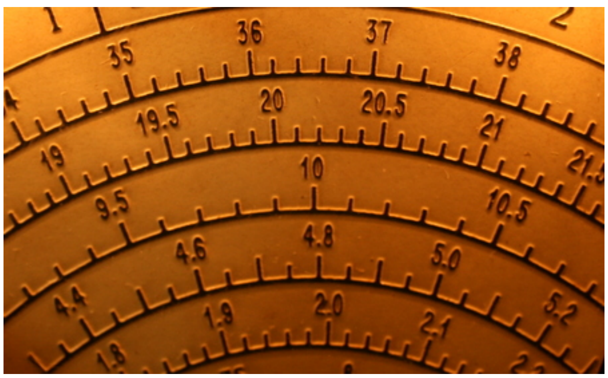
This entry was posted in AM, Broadcasters, News, Nostalgia, Pirate Radio, Radio History and tagged Crystal Radio, Radio Caroline, République No.6 on August 9, 2015 [https://swling.com/blog/2015/08/radio-caroline-and-a-crystal-radio-the-making-of-a-rebel/] by Thomas.

Listener Post: Greg Blair



Greg Blair's radio story is the latest in our series called *Listener Posts*, where I place all of your personal radio histories.

If you would like to add your story to the mix, simply send your story by email!

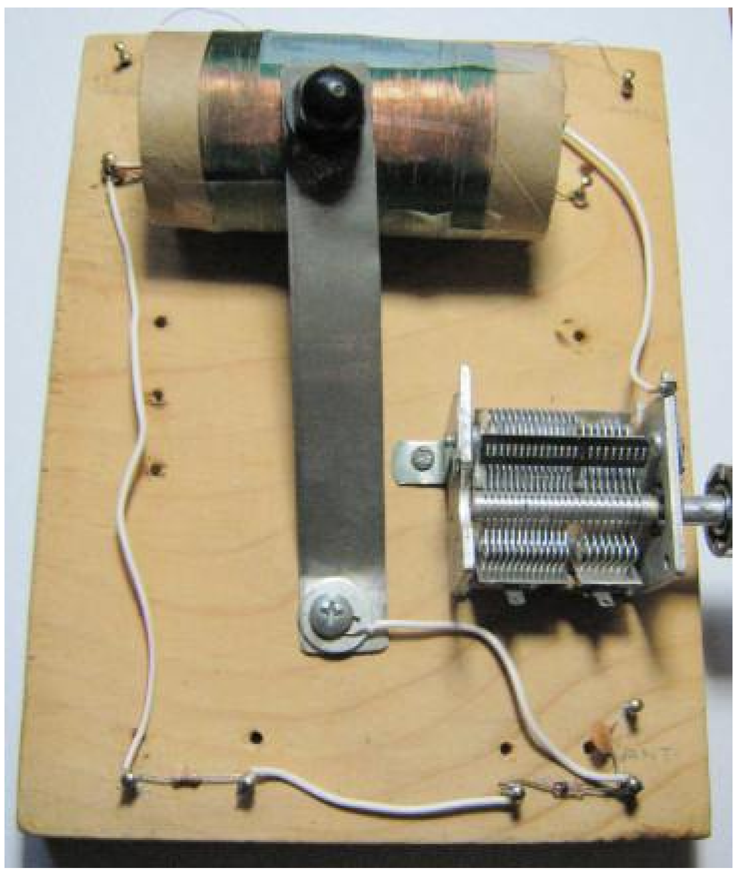
In the meantime, many thanks to Greg Blair who originally posted the following on the Shortwave Listeners Worldwide Facebook group. Greg writes:

How I Discovered Shortwave Radio

I discovered shortwave radio almost by accident.

I had built a simple crystal radio from plans in a library book…(I think it was "The Boy's Book of Radio" or similar.) I added a one transistor amplifier later. I had a really great long wire antenna from the garage to the house, up about 30 feet, about 75 feet long, and a good earth ground.

I was playing around with it, and I had an old phonograph amplifier I connected to the output of it. I de-tuned the coil and apparently managed to get it tuned into the 49 meter band. All of a sudden I was hearing broadcasters from Europe. Some were in English, others in foreign languages.



Up to that point I had thought that all radio was like AM broadcast, only good for a few hundred miles even at night. I was flabbergasted. That marked the beginning of my addiction to radio. I have never gotten over the miracle of HF radio ever since.

Many thanks, Greg, for sharing your memories with us!

I can only imagine the thrill is must have been to tune in stations from across the planet on your simple, home-brew radio set.

I encourage other *SWLing Post* readers and contributors to submit their own listener post! Tell us how you became interested in radio!

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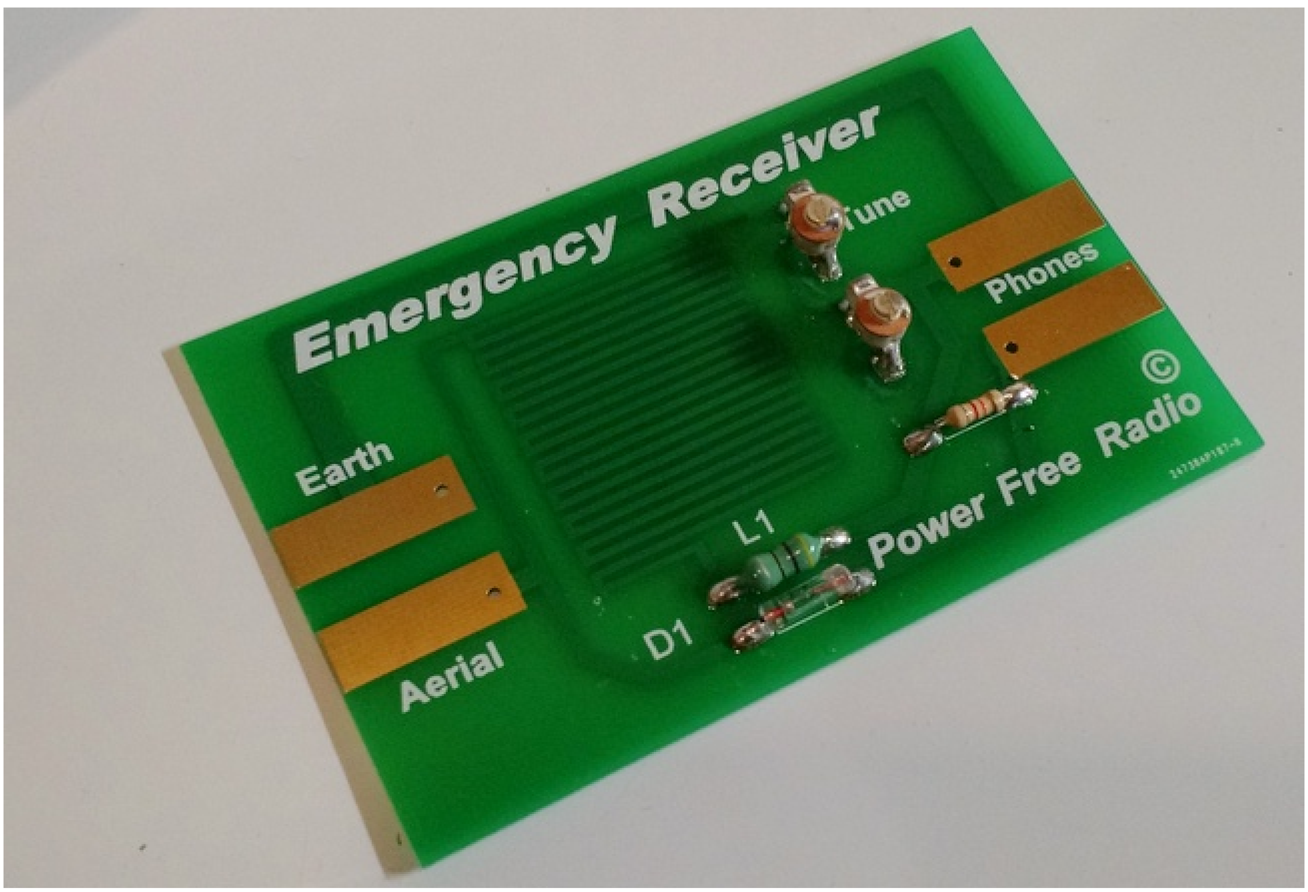
This entry was posted in How To, Listener Posts, News, Shortwave Radio and tagged Crystal Radio, Greg Blair, Listener Posts on May 6, 2015 [https://swling.com/blog/2015/05/listener-post-greg-blair/] by Thomas.

Tinkering with the Credit Card Crystal Radio



A few weeks ago, we published a short post about a credit card crystal radio from an eBay seller in the UK.

I purchased a kit–at $17-18 US shipped, it's quite a modest investment for what might be a fun little project.

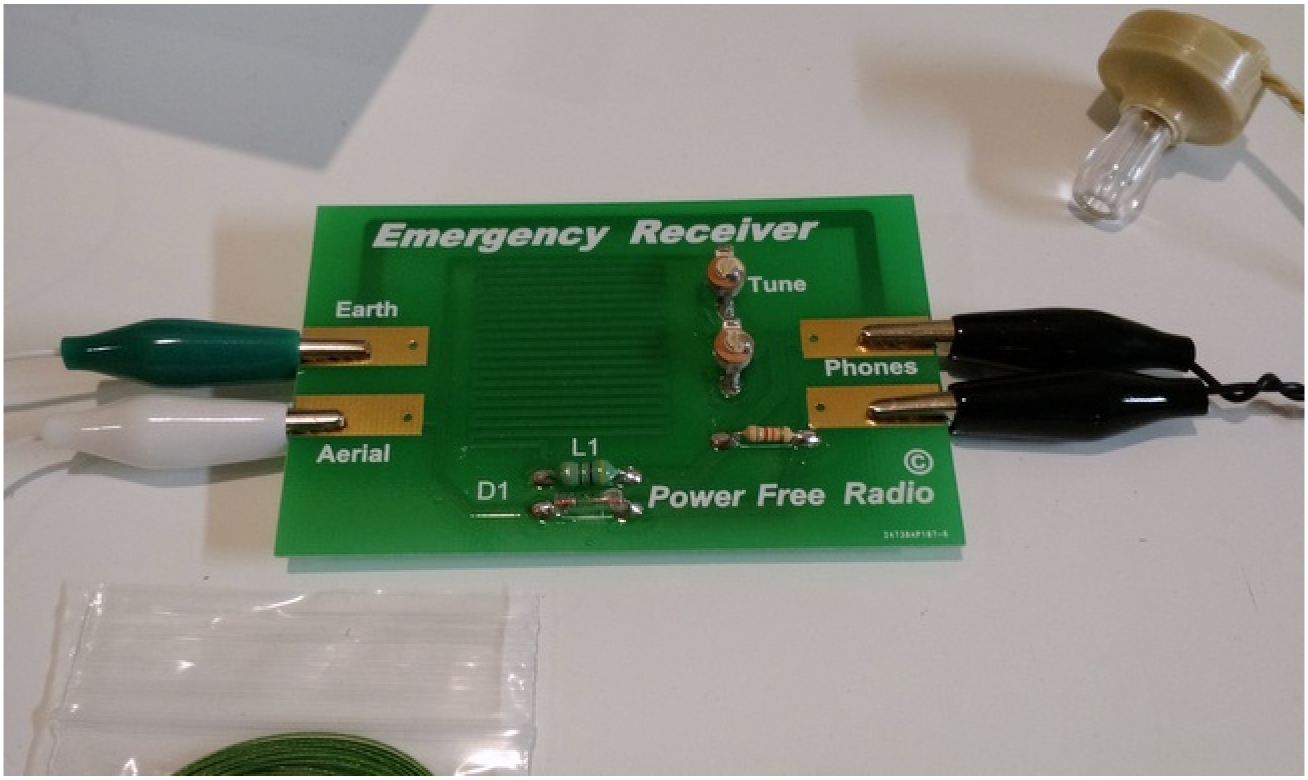
The crystal radio arrived while I was traveling during Easter break, but my free time has been so (extremely) limited lately, I was only able to unpack and try out this new arrival yesterday.

The biggest surprise for me was the fact that this isn't really a kit–the board is fully populated and requires no soldering whatsoever. The board feels of very good quality.

All that is required is connecting the high-impedance earphone, earth/ground and aerial/antenna to the board. Since all of these components can be connected with the supplied alligator clip cables, getting it on the air took all of 20 seconds. I simply hooked up the ground and connected the aerial to my sky loop wire antenna.

I instantly heard a signal and station ID which confirmed it was our closest local broadcaster on 1010 kHz. This station isn't of the blowtorch variety, but is the strongest one I receive on the MW band simply due to its proximity. Audio was quite faint through the earpiece, but I believe if I tinkered with antenna length and the two variable capacitors, I could improve reception.

SWLing Post reader, Richard Langley, received his crystal radio and had a very similar experience with reception.



With any crystal radio (especially one this small), performance is directly correlated with antenna length, availability of a good ground connection and, of course, strong broadcasters in your vicinity.

I plan to spend an evening tinkering with this little receiver and see if I can pick up some of the night time powerhouse AM stations on the east coast.

I can say this: if you're looking for a simple, uber-compact emergency receiver for your go-bag, bug out bag or emergency kit, this one will certainly fit the bill. This crystal receiver and all of its components weight no more than a few ounces and could easily fit in compact pouch or sleeve.

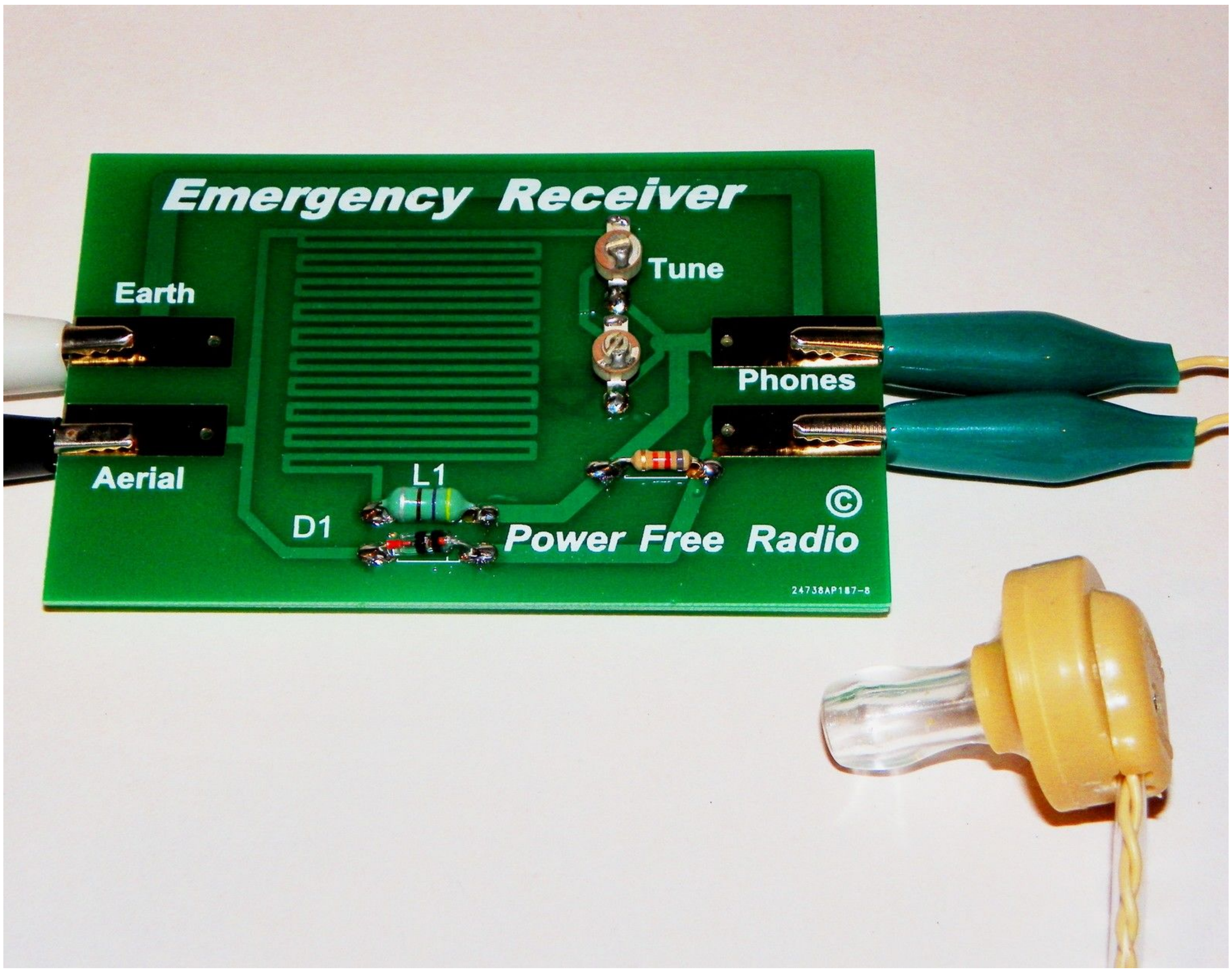
Have any other readers have enjoyed tinkering with this little emergency crystal radio?

If you would like to purchase one, try searching eBay with one of the links below. The product will only appear in the search results if currently available.

- Search via eBay US (best if you're in the USA, but scroll to bottom of screen to see this item under "International Sellers")
- Search via eBay UK (best if in UK or EU)

This entry was posted in AM, How To, Kits, Mediumwave, News, Radios, Reviews and tagged BOB Radios, Bug Out Bag Radios, Crystal Radio, Crystal Radio Credit Card Receiver, Crystal Radio Kit, Emergency Radio, Medium Wave on April 14, 2015 [https://swling.com/blog/2015/04/tinkering-with-the-credit-card-crystal-radio/] by Thomas.

Crystal radio credit card receiver



On a tip from my good friend Dave Cripe (NM0S), I just purchased this cute crystal receiver kit from a UK-based seller on eBay.

The price is 8 GPB plus 3.50 GPB for shipping. After PayPal currency conversion, I paid $17.63 US shipped from the UK–a *very* fair price. The kit is supplied with 5 meters of antenna wire, a high impedence earphone fitted with crocodile clips, and two double crocodile clip leads. Each unit is also tested prior to shipping. The seller also has a 100% positive rating on eBay.

I'll certainly make a post about the radio once I receive and build it. While there aren't as many blowtorch broadcast stations to hear these days via a crystal set, with an ample length of antenna wire, you may be surprised what you will hear. Certainly a fun and lightweight item to take camping or place in your bug out bag. No batteries required!

Update: Since making this post, it appears the item number has changed since the seller had to list a new lot of kits. Below, I've made two links that search eBay based on the description, not item number:

- Search via eBay US (best if you're in the USA, but scroll to bottom of screen to see this item under "International Sellers")
- Search via eBay UK (best if in UK or EU)

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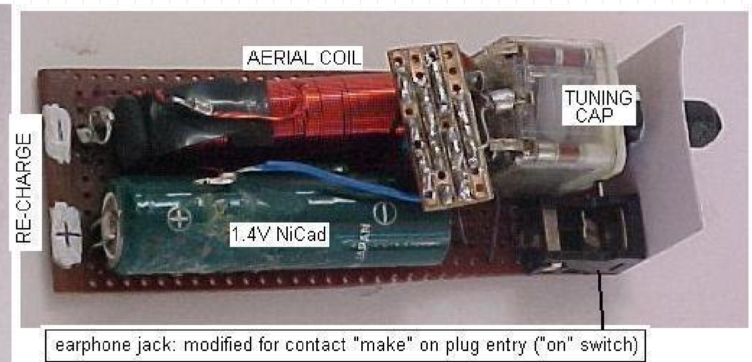
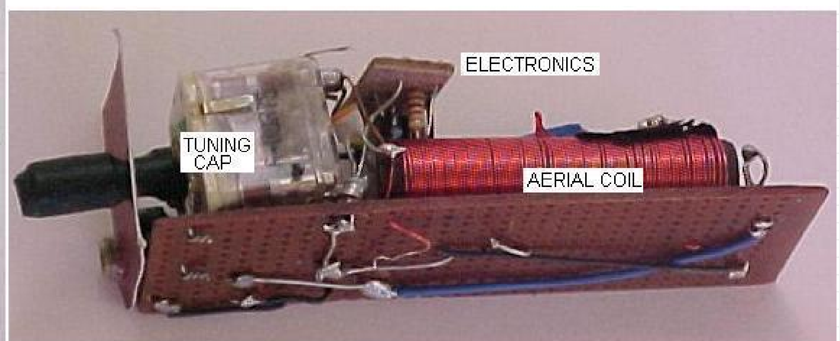
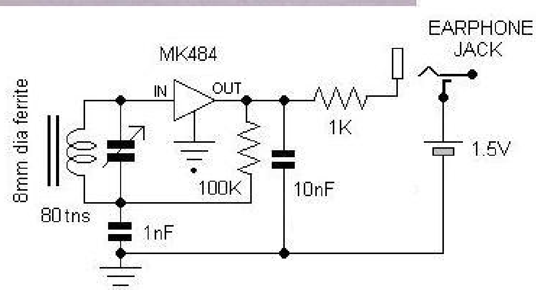
This entry was posted in AM, Kits, Mediumwave, News and tagged Crystal Radio, Crystal Radio Credit Card Receiver, Crystal Radio Kit, Kits, Radio Kits on March 21, 2015 [https://swling.com/blog/2015/03/crystal-radio-credit-card-receiver/] by Thomas.

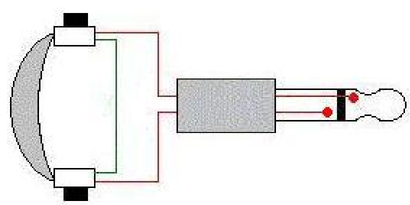
MK484 featured Radio Designs

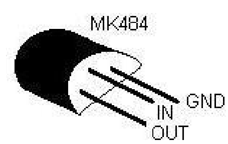
The following is a collection of radio receiver designs which use the popular MK484 "radio on a chip".
This device is a 3 terminal (TO92) package; which has only in/out/gnd terminations.
See manufacturers data sheet for further info.











This is a radio of my own construction in which I managed to fit all componentry into a small (recycled) plastic food container.
It is one (NiCad) cell powered and will fit in your shirt pocket.

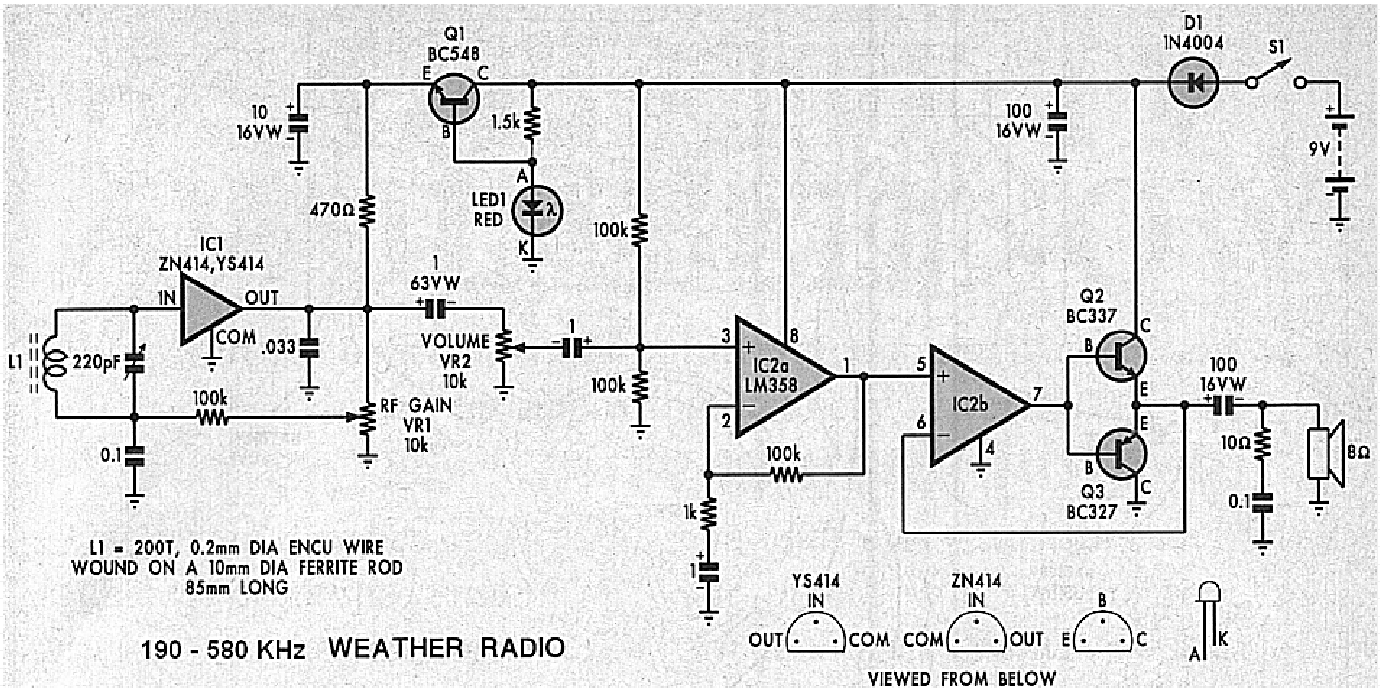
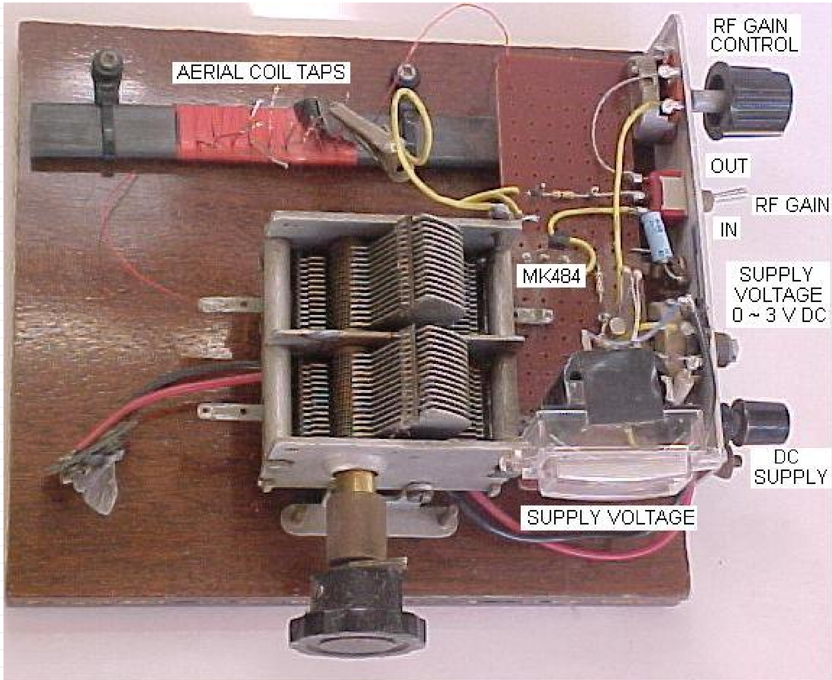
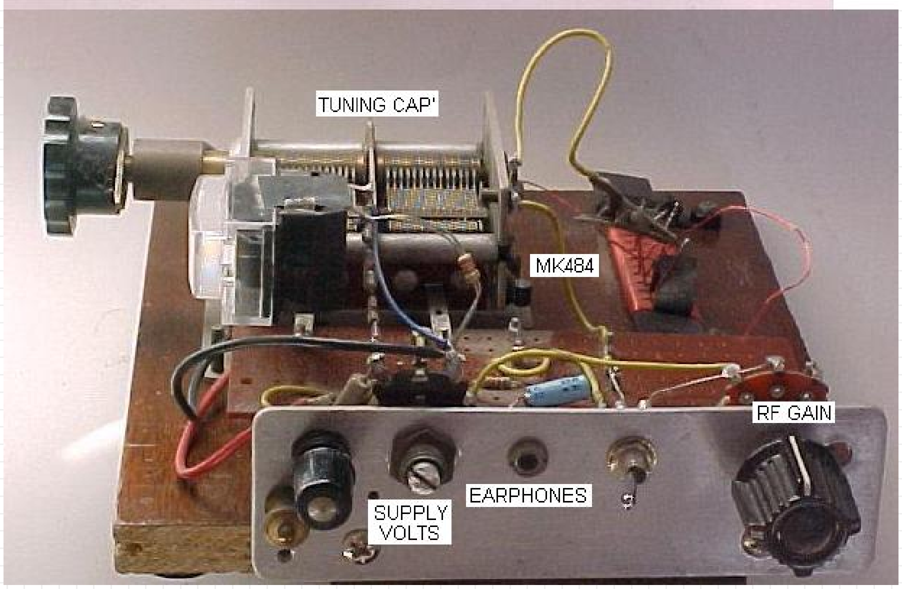


Fig.1: the circuit is essentially a TRF (Tuned Radio Frequency) design based on a ZN414 radio IC. This tunes over the long-wave band & feeds the recovered audio to VR2. The audio stages comprise IC2a & IC2b which drives a pair of complementary emitter followers (Q2 & Q3).

From SILICON CHIP Mag' (Australia) Sept 1994 pg 54. "AM receiver" design: Darren Yates

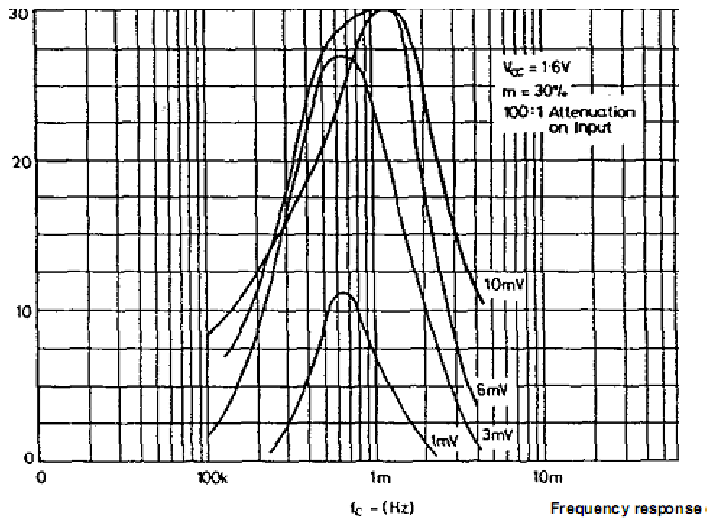
This elegant design from Darren Yates sited in Australian "SILICON CHIP" magazine, and is as good as you'll find. It is similar to my "Cigar-Box" radio shown elsewhere.





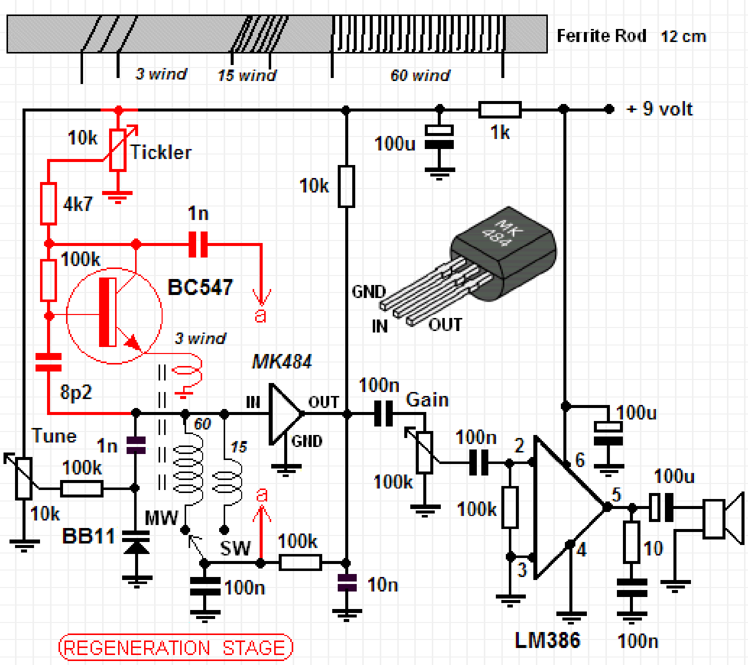
This is a "breadboard" construction MK484 based receiver, circuit being very similar to Darren Yates "Weather Radio".
I was trying to experiment to see what effect, An RF gain control, variation of chip supply voltage (0 to 3 volt) and altering the LC tuning (in order to tune higher than Broadcast frequencies) would have.
Some info floating around the internet would suggest that the MK484 may work in the 80 metre and possibly the 40 meter amateur band assignments!
I found this to be completely untrue as these chips will only function below about 3 Mhz effectivley.
The manufacturers frequency plot will affirm this fact.

Item	Symbol	Min	Typ	Max	Unit
Supply Voltage	V_{CC}	1.1	1.4	1.8	V
Output Voltage	V_{OUT}	0.8	-	1.5	mV
Drain Current	I_{CC}	-	0.3	-	mA
Cover Range	f_R	150	-	3,000	KHz
Input Resistance	Z_{IN}	-	4	-	MΩ
Total Harmonic Distortion	-	-	4	-	%
AGC Range	A_{GC}	30	-	-	dB
Power Gain	G_P	-	70	-	dB

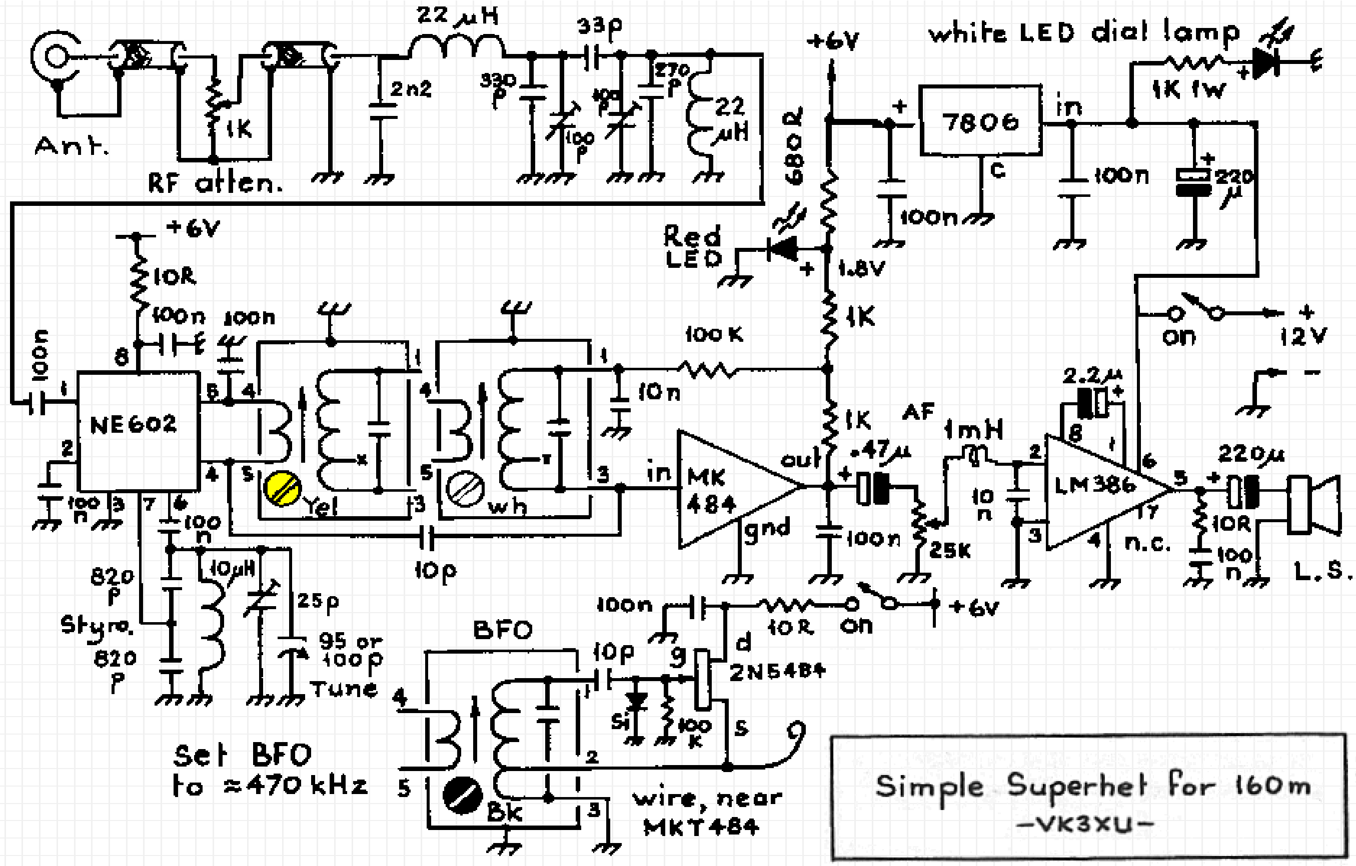


Note that this graph represents the chip response, and not the receiver bandwidth.

Notwithstanding the above; this is a [regenerative MK484 design]I found on a (Dutch) website.
I haven't constructed it, but it purports to be able to tune up to 7MHz by using a regenerative transistor input stage to obtain the necessary sensitivity.
Seems like a good idea, but only a working model would reveal its real potential!



Here is another good VK3XU design which uses the MK484 as a fixed frequency (470KHz) I.F. amplifier.
Ingenious; as the MK484 contains about 10 active transistors incorporates several RF stages, automatic gain control and an AM detector.



Amateur Radio December 2007 160 m simple superhet receiver.

I have not tried anything like this, however a functioning demonstration on YouTube of the design is at:

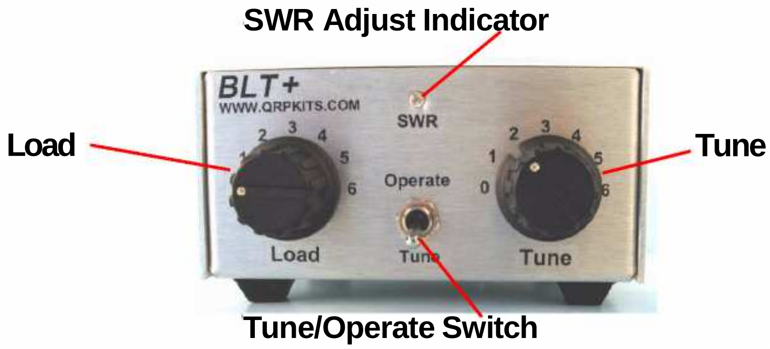
You Tube http://www.youtube.com/watch?v=qdlXVKOITe4

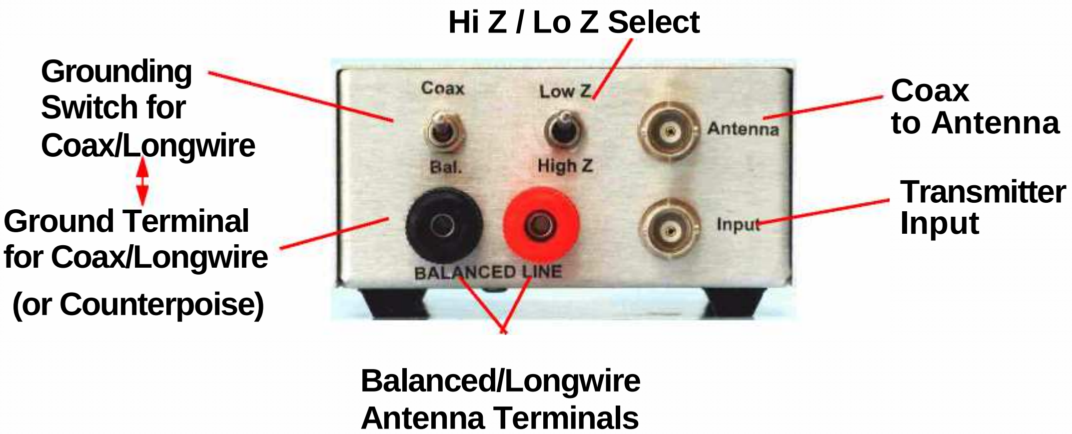
QRP Kits

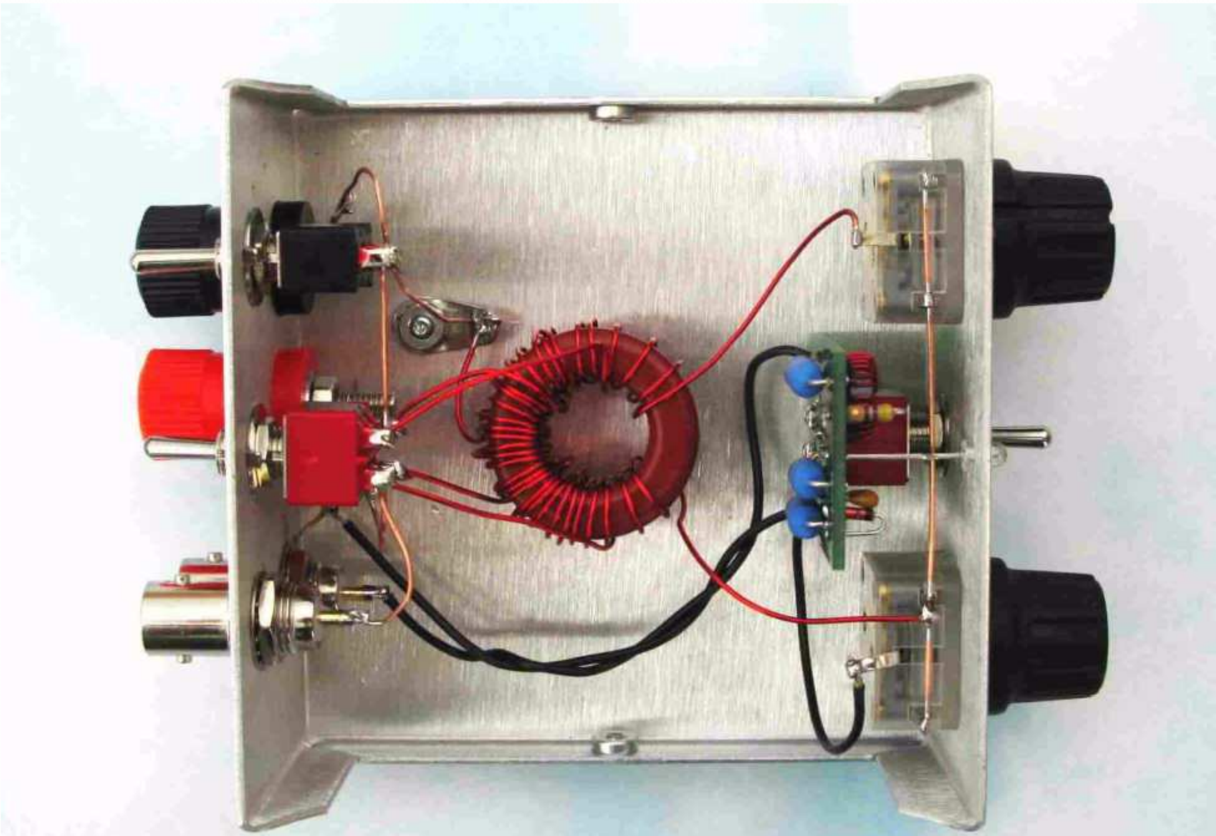
Affordable QRP kits at exceptional value

BLTplus

Assembly and Operation Guide v2






BLTplus Inside View

Contents

Figures and Illustrations

Manual prepared by W5USJ

QRPKits BLTplus+

QRPkits BLTplus+ is the second generation of the popular QRPkits QRPplus. New features include:

- Revised prepunched enclosure front panel
- New visual SWR assembly
- Uncluttered interior assembly and wiring
- Decals for labeling providing a finished professional look

Decals must be affixed to the enclosure before doing any assembly!

Note: Assembly Instructions for the visual SWR bridge are located at:
http://www.qrpkits.com/swrindicator.html
Log on and download them before starting BLT+ assembly

Background

The following is an updated version of the background section written by Doug for the original NorCal BLT manual.

NorCal's original BLT was designed by Charlie Lofgren, W6JJZ who is renowned in the QRP world as a z-match tuner expert. Charlie has built all the tuners used by the Zuni Loop QRP Expeditionary Force for years. They all swear by them.

The original tuner was a balanced line tuner only, and would not work with coax feedlines unless modified as shown in the mods section of the original manual. It worked great with open wire feeder, ladder line, zip cord and even computer ribbon cable. As long as you used balanced line as a feedline, the BLT would work.

Charlie designed the tuner to work specifically with the polyvaricon variable capacitors that used to be sold by Mouser. I asked him to design it at first because I wanted a simple tuner for a presentation that I was doing at the Ft. Smith QRP Group Forum, ArkiCon 2000. It turned out so well that everyone who saw it wanted one. Thus the NorCal W6JJZ BLT kit was born. I would like to thank Charlie for his efforts on behalf of NorCal. This one is going to be a classic.

The design is for a classic Z-Match using inductive coupling with L1, L2 and L3 wound on a single T106-2 toroid. L2 or L3 is switched in and out of the circuit by switch 2 located on the back panel of the tuner. The "high" and "low" positions on the switch for the output links may need clarification. The positions are for "high" and "low" in terms of impedance not frequency. For a given band and antenna try the High Z link first and use the Low Z link only if a match can't be found with the high link. (Often either link will allow a match. In these instances, the High Z link produces better efficiency as a result of

loading the tank circuit more heavily.) [Better coupling]

The circuit also includes the famous N7VE LED SWR indicator circuit. Dan Tayloe invented this several years ago and it has proven a great addition to the QRP fraternity. This allows us to have an indication of lowest SWR on the tuner (indicated by the dimming of LED going out at minimum SWR).

Note: The N7VE SWR kit is now included as part of the BLTplus+

The circuit also includes an absorptive bridge which means that your transmitter sees a 50 Ohm load as you are tuning up. This will help to save your final transistors! This tuner is rated at 5 Watts. I doubt if the polyvaricon caps will take the 100 Watts of your big rig! Now, lets get started to build the kit. First of all, you will need the following tools: 25 – 30 Watt soldering iron, drill, 1/8" bit, small Phillips screw driver, small blade screw driver, pliers, diagonal cutting pliers, needle nose pliers and about 4 feet of #24 solid insulated hookup wire. A Volt/Ohm meter is helpful also. Please read the manual in its entirety before you start building. You may want to print out the schematic, parts layout, parts list [LOM] and wiring diagram.

Note: Update meters to include Digital Multi Meters (DMMs/D VMs).

Parts Inventory

Before starting the assembly, inventory the parts and verify that you have the parts described in the following list of materials (LOM).

List of Material

N7VE LED SWR Kit
    Download instruction manual for kit LOM
C2, C3 – 160/60 pF Dual Polyvaricons
SW2 – DPDT Toggle On/On
SW3 – SPDT used as On/Off or SPST On/Off
J1, J2 – BNC Jacks, Single Hole Mounting
J3, J4 – Red and Black Binding Posts
T2 – 16t Primary Center Tapped, 12t Secondary 1, 6t Secondary 2
    Wound on T106-2 Toroid
4ea – 3x2.6mm Pan Head Screws
2ea – 12x2.6mm Pan Head Screws
2ea – 1/4 x 3/8 Nylon Bushings
6 feet – #22 Green Wire
2ea – Black Knobs
1 – #4 Internal Tooth Solder Lug
1ea – 4/40 x 1/4 Panhead Screw
1ea – 4/40 Nut
4ea – Bumpers/Feet
Prepunched Enclosure
Panel Decals
Decal Instructions
    Download instructions from the qrpkits.com website

Additional materials needed for assembly:

12 inches – #22 Bare Hookup Wire
3 feet – #22 Insulated Hookup Wire
A/R – Solder

Note: Some supplied parts may vary in size, shape and color from those shown in the pictures but the values will work the same.

Prepare Enclosure

Note: Provided decals must be affixed before starting any assembly.

If you decide to use the decals, download the instructions for applying the decals from the qrpkits.com website.

Decals

Follow the methods and procedures described in the instructions for the affixing the provided decals.

Optional Finishes

If you would like a finish other than brushed aluminum, you can apply a paint color of your choice. Using a light colored paint will ensure that affixed labels or the included decals will be highly visible. If you decide the leave the aluminum unpainted, you may still want to keep it looking nice. A clear coat of a satin finish could be applied to prevent fingerprinting and minimize oxidation.

Do any optional preparation and finishing of the enclosure before doing any mechanical assembly. Allow time for finishes to properly cure. Follow the instructions provided with the finish you choose.

Attach Ground Lug

Using a 1/4 inch 4-40 screw, 4/40 nut and internal tooth ground lug, install and orient as shown in Figure 1.

Figure 1 Attach Ground Lug

Affix Feet/Bumpers

Affix a foot/bumper at each of the four corners of the enclosure bottom.

Assemble Back Panel

Assemble the lower row of parts on the back panel starting with the black binding post. Note the orientation of the solder lugs.

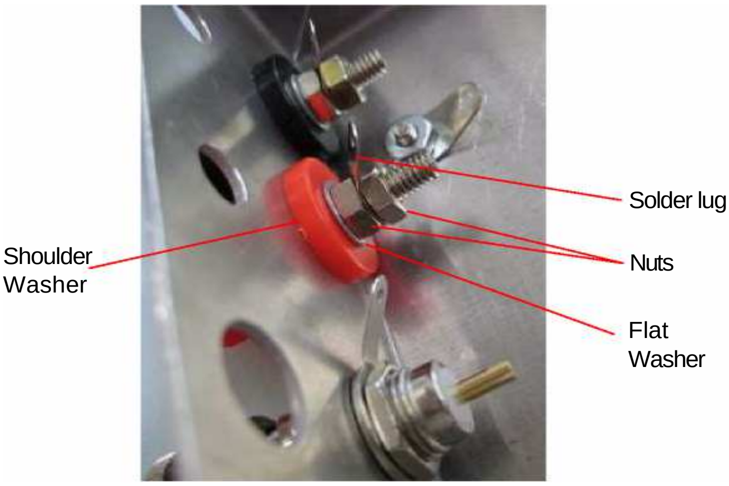


Figure 2 Backpanel Assembly

The assembly sequence used here will facilitate tool use and wiring.

Start the assembly with the black binding post. Then the red post and finally the lower coax connector. Also see Figure 4 below.

Black Post – disassemble the parts then reassemble in reverse order except for the two nuts and solder lug. Place the solder lug between the two nuts. Orient the solder lug about 45 degrees toward the outside of the enclosure.

Red Post – same procedure except orient the solder lug about 45 degrees in the opposite direction.

BNC connector – assemble with the lock washer next to the panel under the solder lug to ensure a good ground. Orient the solder lug toward the red post. It helps to use a BNC connector as a holding tool during the assembly.

DPDT switch – Assemble the top row starting with the middle DPDT switch. Adjust the position of the nuts and lock washer such that there are about two threads showing when the nuts are tightened.

SPST (or SPDT) switch – assemble in a similar fashion.

BNC connector – assemble in a similar fashion to the lower connector. The solder lug is not required. If used assemble as described above.

Wire and Solder Back Panel

Using short lengths of bare hookup wire, connect the binding posts, switches, coax connector and ground terminal as shown in Figure 3 below and the wiring diagram on page 23.

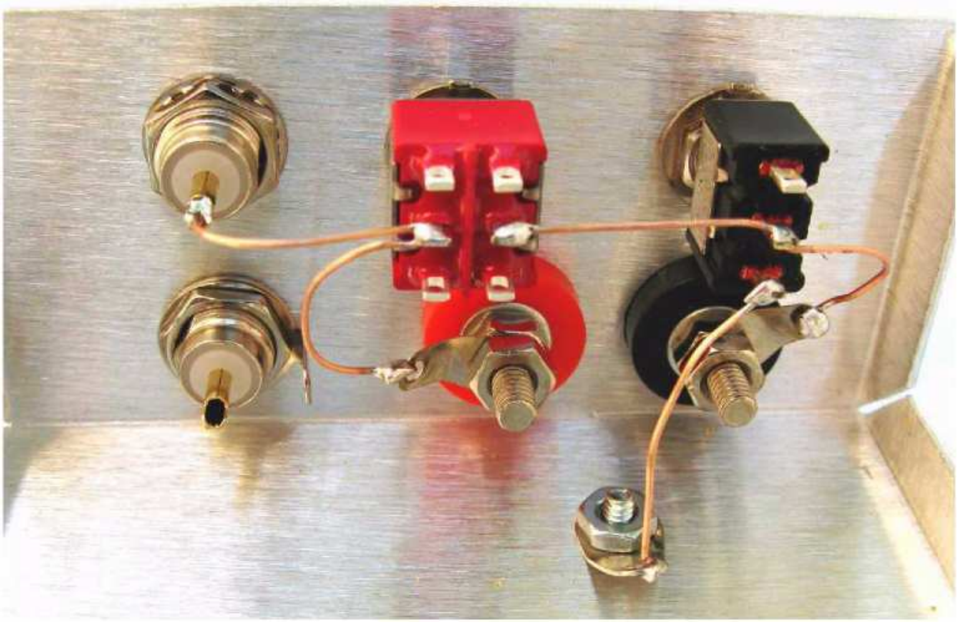


Figure 3 Backpanel Prewiring

Solder the connections to the binding posts, switches and coax connector. Leave the ground terminal until transformer T2 is connected later.

Assemble Front Panel

In this section, variable capacitors C2 and C3 are prepared for assembly onto the enclosure front panel. Next, they are mounted and wired.

Prepare Capacitors for Assembly

Using a 12 x 2.6mm screw attach a nylon spacer to each capacitor as shown in Figure 15 below.

Note: to prevent damage do not force the capacitor shaft against the stops when tightening the screw.

Set the trimmer capacitors to minimum as shown in Figure 4 below

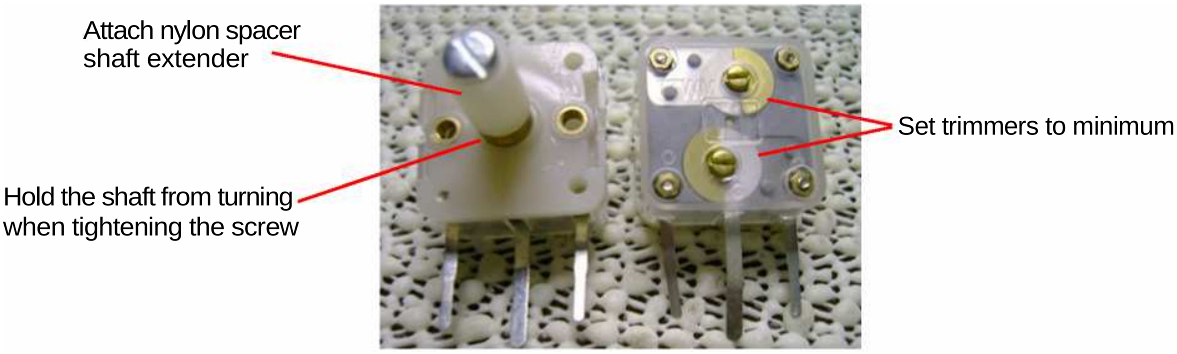


Figure 4 Preparing Capacitors

Using two 3 x 2.6mm screws attach the capacitors to the front panel. Verify that the screws do not extend into the capacitors and hit the plates. Orient the capacitors with the terminals up.

Wire Capacitors C2 and C3

Trim the capacitor terminal length to about5/16 inch and carefully form a U bend.

Using a length of bare wire carefully crimp the four rear terminals around the wire, solder and trim off any excess. See Figure 5 below

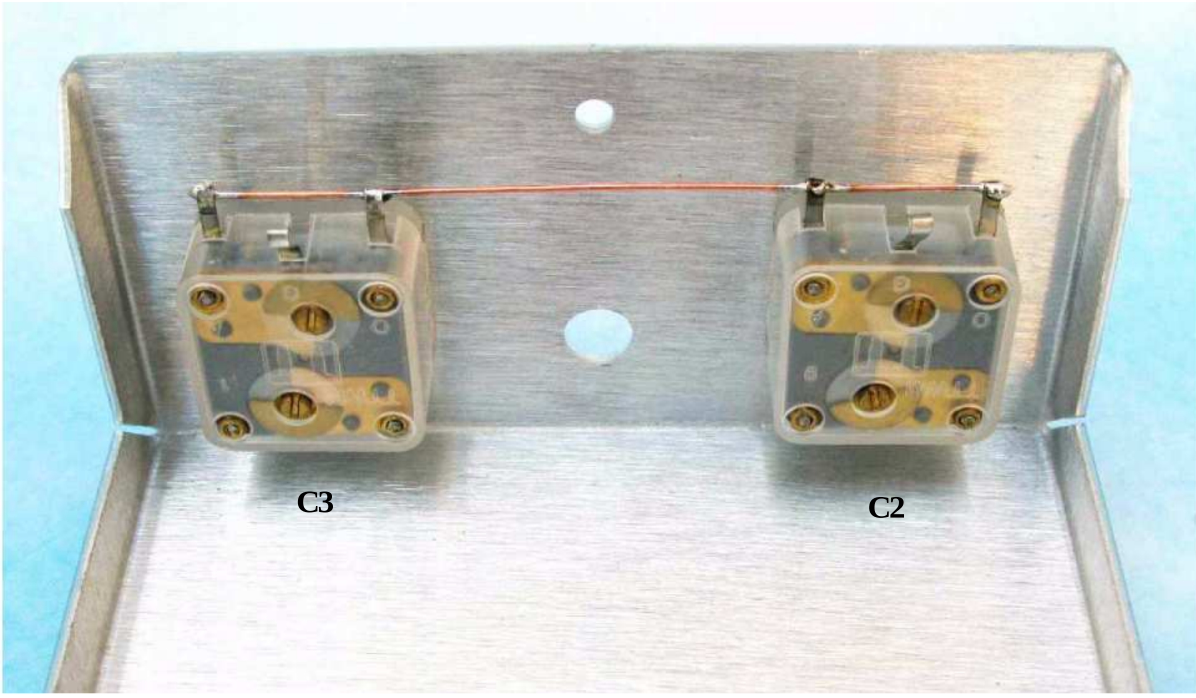


Figure 5 Wiring Capacitors C2 and C3

The two front common capacitor terminals will be connected during the final wiring process.

Note: The trimmers on the capacitors used for this illustration were not set to minimum as described on page 12. You need to do that.

Assemble N7VE LED SWR Kit

If you haven't already done so, download the instructions from the qrpkits.com website. Except for the installed height of the LED as shown in Figure 6 below, assemble the VSWR kit according to bridge manual instructions.

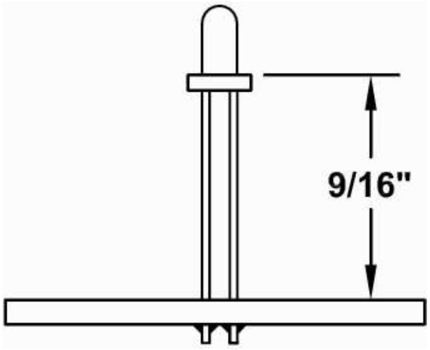


Figure 6 LED Assembly Height

Connect SWR Bridge Wires

Cut and strip the ends of three length of hookup wire.

SWR to C2 = 2 inches
SWR to J1 Center pin = 3.5 inches
SWR to Ground Lug = 3 inches

Attach the wires to the PCB as shown in Figure 7 below.

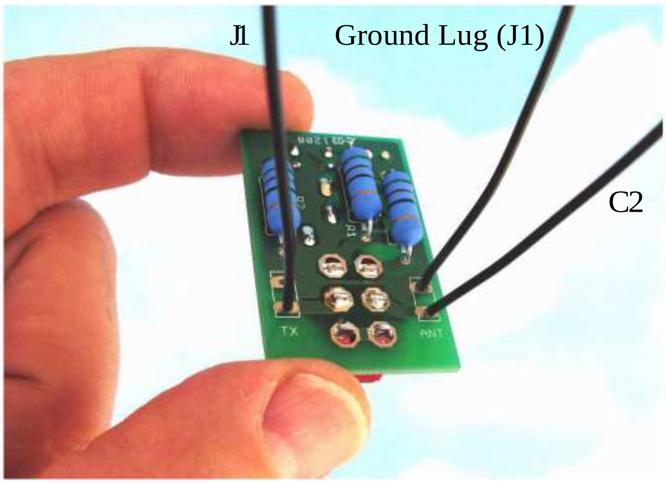


Figure 7 Attach SWR Bridge Wires

You may want to use a black wire for the ground connection and a different color for the connections to J1 and C2.

Gently twist the wires, about 1 turn per inch, that will be connected to the J1 center pin and J1 ground lug.

Using the hardware included with the SWR bridge toggle switch, attach the SWR bridge assembly to the front panel.

Adjust the back nut so as to position the LED and the switch in the same plane on the panel. See Figure 8 below. Tighten the nut.

Note: Ensure that the LED wires do not touch the interconnecting wire between capacitors C2 and C3.

Figure 8 BLTplus Inside View

After twisting the 3 and 3.5 inch wires:

Connect the 2 inch wire to the tab on C2,
Connect the 3 inch wire to the ground lung at J1,
Connect the 3.5 inch wire to J1 center terminal,
and solder the connections.

Winding Output Transformer T2

BLTplus output transformer, T2, consists of a center tapped primary winding, L1, and two secondary windings, L2 and L3. The appendix section, page 21, includes a drawing that provides information to facilitate the winding process.

Referring to the drawing, the winding steps are:

- Choose which center tap option will work best for you
- Choose which of the winding connection methods you'd like to use
- Form the center tap for winding L1
- Wind the16-turn primary L1 on the toroid
- Wind the 12-turn secondary L2 on the toroid
- Wind the 6-turn secondary L3 on the toroid

If you choose to make connections to the transformer with hookup wire the additional steps are:

- Cut the transformer leads down to about 1/2 inch and strip 3/8 inch
- Form a loop at each wire end and connect a 2-inch length of hookup wire

Your finished transformer should resemble the illustrations on the drawings.

Connecting Transformer T2

Refer to the wiring diagram drawing in the appendix section, page 23, and the inside view of the BLTplus, Figure 8 on page 15.

You may find it useful to put a temporary spacer about 1/4 inch thick under the toroid to position it away from the enclosure.

- Position the wound toroid and route the leads as shown in the pictures.
- Place the wires in the position they will be when attached and cut them to length. Leave enough slack for connection and soldering.
- Strip about 1/4 inch of insulation from the end of each wire.
- Connect secondary wires L3c and L3c' to the bottom terminals of S2
- Connect secondary wires L2b and L2b' to the top terminals of S2
- Connect primary wire L1 a' to the center lug of C3
- Connect primary wire L1a to the center of the wire between C2 and C3

Final Assembly Checkout

Inspect carefully for good solder connections and ensure that there are no shorts, incorrect or missing connections. Use the wiring diagram from the appendix section page 23 as a guide. Also, compare the wired assembly to the schematic on page 22.

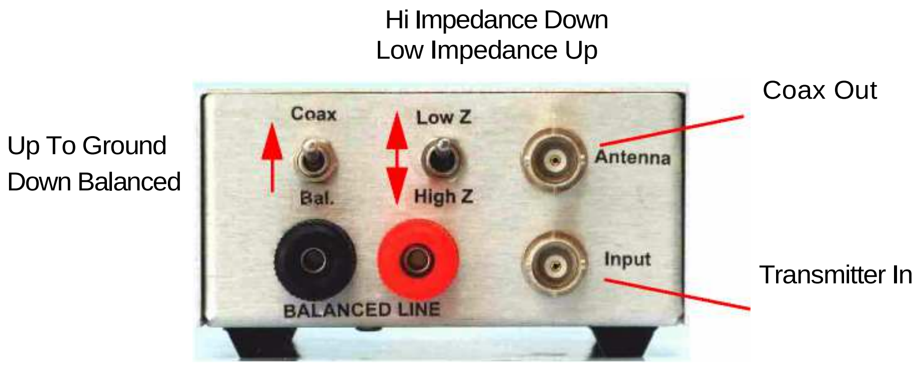
Notes

BLTplus Operation

BLTplus is designed to "tune" or match your transmitter to typical antenna systems for the 40, 30, and 20 meter amateur bands. Under ideal conditions, where the impedances and SWR are not at extremes, you may be able to adjust for a match on higher frequency bands.

Antenna Connections

Connections for various types of antennas are shown in Figure 9 below and described in the following text.



Switch positions are correct when wired as described in this manual

Figure 9 Back Panel Connections

Connect your transmitter output to the transmitter input BNC jack. Depending on the type of antenna you will be using select the connections and settings as follows:

Note: The grounding switch connects the black binding post to the BLTplus chassis ground. A physical ground (earthed) connection may also be used when conditions require one.

- Connect balanced feedline to the red and black binding posts. Leave the grounding switch in the down position.
- Connect end fed longwires to the red binding post terminal. Connect a counterpoise wire to the black binding post. Place the grounding switch in the up position.
- Connect coax to the coax out jack. Place the grounding switch in the up position.

Adjusting for a Match

With your transmitter and antenna connected to the tuner, set the tune/operate to the tune position. Set the adjustment knobs to the center position.

Note: Tune mode, BLTplus maximum power Input – **5** Watts

Place the HI/Low impedance switch in the Hi position. The Hi impedance setting provides the most efficient coupling and operation.

Briefly key your transmitter and attempt to adjust the knobs to dim the LED.

Continue adjusting back and forth until the LED is out or is as dim as possible.

If the adjustments do not produce adequate dimming of the LED switch to the Low impedance position and repeat the adjustment process.

Note: Under some conditions of match adjustment the LED will not go completely out. Your antenna will be tuned for proper operation even if the LED does not dim completely out.

Switch the tune/operate switch to the operate position. Work those DX stations.

Figure 10 Tuner Controls

Experiment and Customize

BLTplus may not work effectively with some antenna systems. You may find it useful to adjust the turns on T2 to provide effective tuning. An excellent resource for experimenting and customizing is the BLT paper by Carey Fuller, NX0R. His paper, in PDF format, can be downloaded from the [QRPkits.com](http://www.qrpkits.com/) website on the BLT page. http://www.qrpkits.com/

Steve, KD1JV, made some mods to the PFR-3 BLT specifically for a 44 foot EDZ using about 50 feet of 450 Ohm window line.
L1= 11t CT at 5/1/2, L2=6t. L3=2t, L2 and L3 centered around the CT.

Appendix

Supplements to help build and operate the BLTplus.

- Output transformer T2 winding information
- BLTplus Schematic
- BLTplus wiring diagram

T2 Center Tap Forming Options

Method 1

Cut wire 28 inches long

Find the center (14 inches)

Carefully strip about 1/2 inch of insulation from the center (1/4 inch each side).

Attach and solder a 1 inch length of bare wire at the center.

NOTE: Wire lengths for the three methods shown above are for connection ver. 1 shown below

Method 2

Cut wires 15 inches and 14 inches long.

Strip about 1 inch of insulation from the end of the 15 inch length. Strip 1/4 inch from the 14 inch length.

Form a small J-hook at the bare end of the 14 in. wire.

Attach the J-hook end to the point where the insulated and bare wire meet. Solder.

Method 3

Cut wire 30 inches long

Find the center (15 inches)

Carefully strip about 1-1/2 inches of insulation from the center (3/4 inch each side).

At the center location, bend the wires tightly together.

Hold the wires firmly with pliers at 3/4 inch from the bend. Twist 2 turns.

Winding the Primary

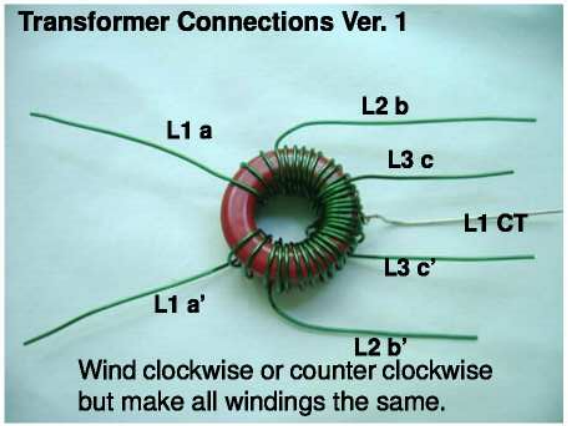
Start the primary winding by positioning the center tap in the center of the toroid. Hold firmly and wind a couple of turns in each direction.

These first windings will hold the wire on the core.

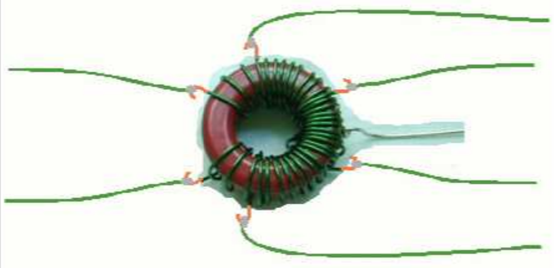
Continue the winding for a total of 8 turns in each direction. Space evenly around the toroid.

Each pass through the middle is 1 turn.

You may find it easier to form the wire against the core by pushing the wire down through the middle.



Transformer Connections Ver. 2
Note: Use 3 inches less wire for this version



Trim lead ends to about 1/2 inch strip to about 3/8 inch. Form a hook end.

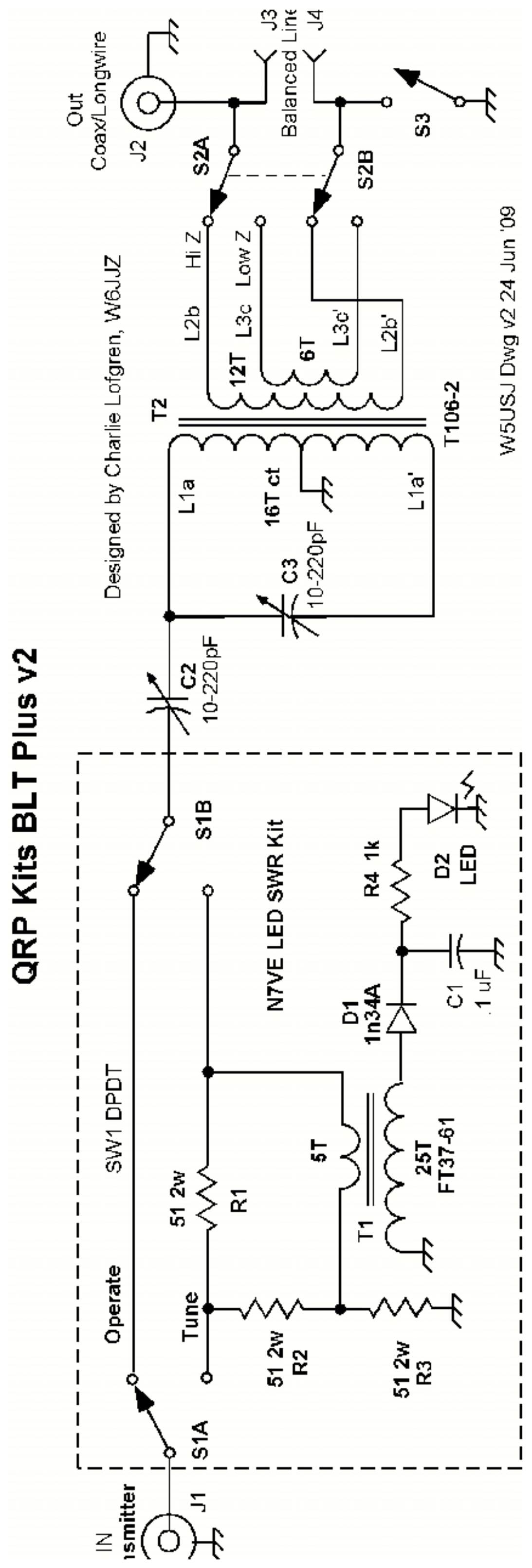
Continue Winding Secondaries:

Find the center of each wire length as the starting point for L2 and L3.

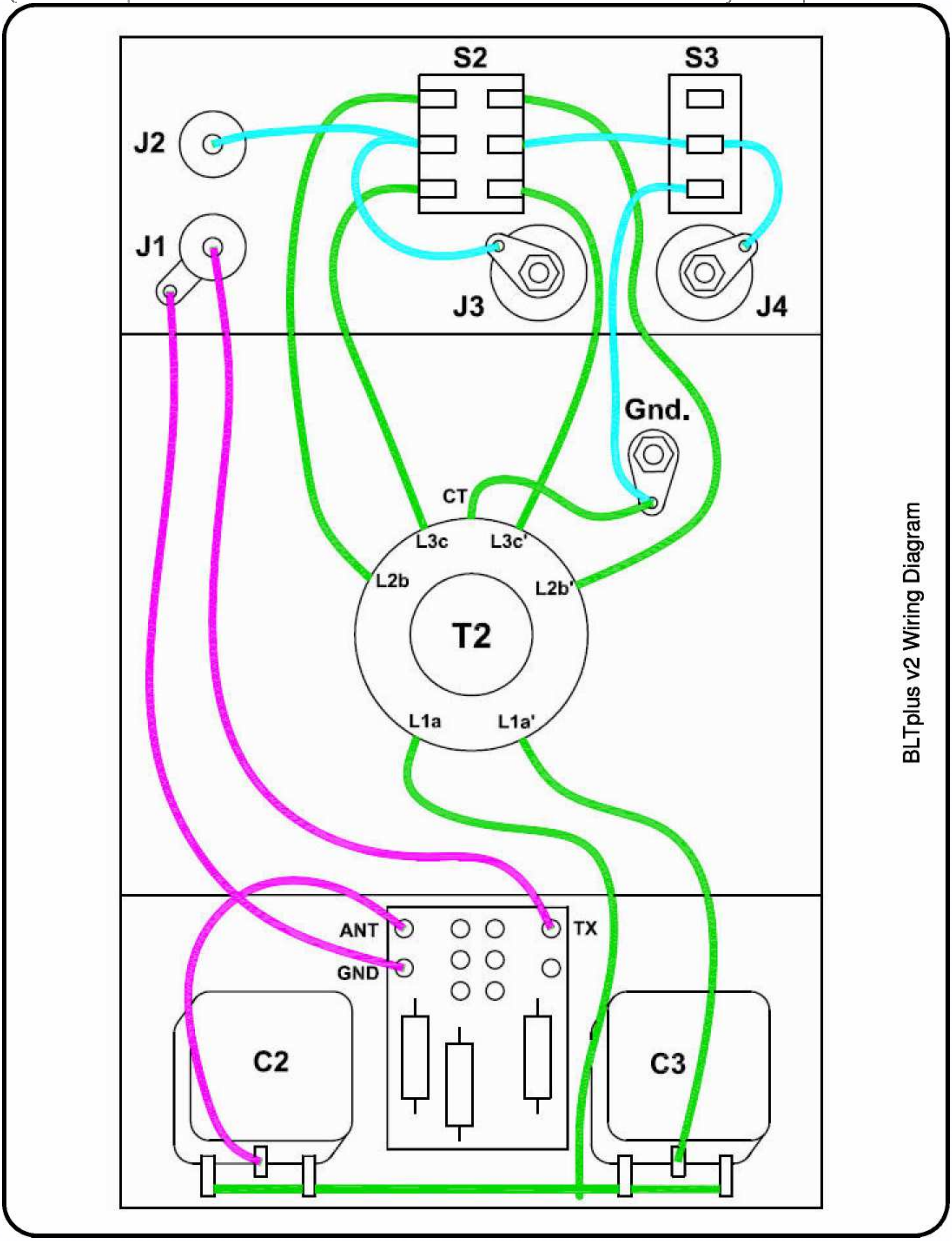
Using a 22 inch length of wire, start L2 at the middle next to the center tap and wind 6 turns each side within the turns of the primary winding.

Using a 13 inch length of wire, start L3 at the middle next to the center tap and wind 3 turn in each direction.

Winding Transformer T2

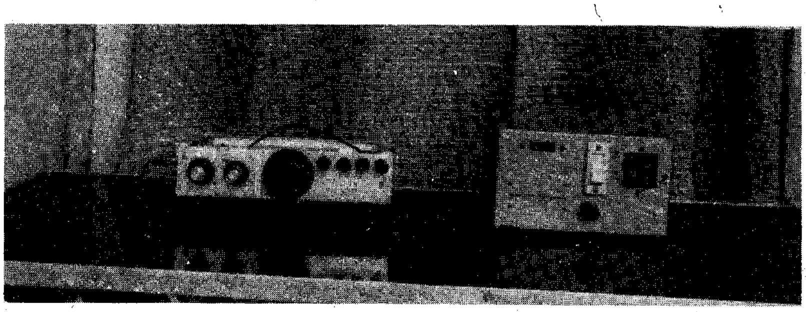


BLTplus v2 Schematic



BLTplus v2 Wiring Diagram

The VU2ATN QRP Transceiver



Atanu Das Gupta, VU2ATN

The transceiver described here is intended for two categories of hams—those who can not afford an imported commercial equipment and those who are tired of operating sophisticated readymade set. It provides an interesting diversion to the hams who are on lookout for a simple QRP CW transceiver. However, they should possess sufficient zeal, enthusiasm and should be ready to face the challenge and uncertainty associated with QRP operation.

The principle of operation

The block diagram of a simple transceiver is shown in Fig. 1. The receiver section is based on direct conversion principle. The signals corresponding to 14 MHz band are converted to audio frequency range in a single step, thus, avoiding multiple conversion technique. Elegant CW note or audio signals corresponding to incoming SSB transmission are available at the high impedance headphone output.

Suppose the incoming signal frequency is 14101 kHz. To produce a beat note of 1 kHz, the local oscillator (in this case the VFO and the quadruppler combination) must be tuned to 14100 kHz or 14102 kHz. Thus, the same signal can be heard twice as the local oscillator is tuned from lower to higher side. For each setting of the local oscillator frequency (LOF), audio output frequency shall be available corresponding to incoming signal which is slightly lower or higher than the LOF. Therefore, the bandwidth is twice that of an equivalent superheterodyne receiver.

The phenomenon of double response is a disadvantage in the direct conversion receiver. But considering the simplicity of the principle, the technique is entirely acceptable and an effective equipment can be built by using it.

The transmitter utilises the same local oscillator, i.e. the combination of the VFO and a quadruppler. Then there are two keyed amplifiers stages. Finally, a broad band amplifier gives output to the antenna through a low pass filter.

The transmitter/receiver control circuit performs following four functions:

1. Provides antenna change-over during receive/transmit operation.
2. Provides keyed DC supply to transmitter amplifiers.
3. Mutes receiver audio during transmission.

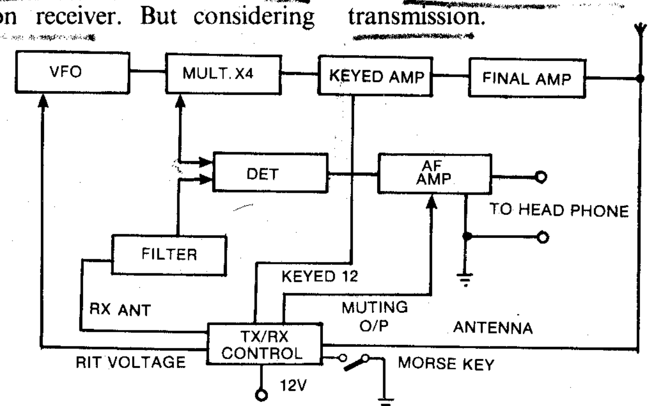


Fig. 1: Block diagram of QRP transceiver.

The author is presently working in National Thermal Power Corporation Ltd. He is associated with the planning and engineering of communication systems associated with NTPC's transmission lines.

PARTS LIST

Semiconductors:

IC1	— 1496, balanced modulator/demodulator
IC2	— 741, op-amp
IC3	— 555, timer
T1	— BFW11, n-channel field effect transistor
T2, T3, T7, T14	— 2N2222A, npn switching transistor
T4, T6	— BF194B, npn RF transistor
T5, T10, T11	— BC148B, npn transistor
T8	— 2N2218A, npn switching transistor
T9	— SL100, npn high voltage transistor
T12, T13	— SK100, pnp high voltage transistor
T15	— ECP055, pnp power transistor
D1, D2, D3, D4	— 1N914, high speed silicon whiskerless diode
D5, D6, D7, D8, D9	— 1N4148, silicon switching diode
D10	— 8.1V, 400mW zener diode
D11	— 1N34, detector diode
D12-D15	— 1N4003, silicon rectifier diode

Resistors [all 1/4W, ±5% carbon, unless stated otherwise)

R1, R4, R48, R52, R54	— 100-kilohm
R2, R17	— 47-ohms
R3, R20	— 33-ohms
R5, R24, R26-R29, R33, R40, R41, R44-R46, R60	— 1-kilohm
R6	— 12-kilohm
R7	— 1.5-kilohm
R8, R42, R51	— 47-kilohm
R9, R18	— 270-ohms
R10, R50	— 4.7-kilohm
R11	— 56-kilohm
R12, R37, R49, R53, R55, R57, R58	— 10-kilohm
R13, R43	— 3.3-kilohm
R14, R19	— 100-ohms
R15	— 27-kilohm
R16, R39	— 5.6-kilohm
R21, R23	— (See text)
R22	— 22-ohms
R30	— 1.2-kilohm
R25, R32	— 820-ohms
R31	— 3.9-kilohm
R34	— 39-ohms
R35	— 10-ohms
R36, R56	— 22-kilohm
R38	— 6.8-kilohm
R47, R59, R62	— 2.2-kilohm
R61	— 50-ohms, 1/2W
R63	— 10-ohms, 2W
VR1	— 1-kilohm, preset
VR2	— 20-kilohm, potentiometer
VR3	— 10-kilohm, potentiometer

Capacitors:

C1	— 500pF, polyester or styroflex
C2	— 150pF, polyester
C3, C5	— 1000pF, polyester
C4, C6, C19, C47, C63	— 0.05μF, ceramic disc
C7, C8, C34, C39, C50-C52, C55, C62	— 0.01μF, ceramic disc
C9	— 2.2pF, ceramic
C10	— 150pF, meshed trimmer
C11, C16	— 50pF, ceramic
C12, C22	— 0.001μF, 50V ceramic
C13, C18, C21, C24, C25, C35-C38, C42, C53, C56, C57, C60, C67	— 0.1μF, 50V ceramic disc
C14, C15, C29, C31, C33	— 100pF, polyester
C20	— 47pF, ceramic
C23	— 47μF, 35V electrolytic
C26, C28	— 220pF, ceramic
C27	— 470-pF, ceramic
C30, C32	— 3.9pF
C40	— 15μF, 25V electrolytic
C41	— 1μF, 10V electrolytic
C43	— 100μF, 16V electrolytic
C44, C46-C49	— 10μF, 63V electrolytic
C45	— 25μF, 25V electrolytic
C51, C52, C55	— 0.01μF, ceramic disc
C54	— 3.3μF, 15V electrolytic
C58, C59	— 0.005μF, polyester disc
C61	— 470μF, 16V electrolytic
C64	— 2200μF, 35V electrolytic
C65	— 0.33μF, polyester disc
C66	— 50pF, gang

Miscellaneous:

X1:	— 18V-0-18V, 1-amp secondary transformer
L1	— Slug-tuned 37 turns close wound with 32 SWG enamelled wire
L2 : W1	— 25 turns closewound with 30SWG
W2	— 3 turns with 30 SWG over the cold end of W1
L3 : W3	— 18 turns closewound with 30 SWG
W4	— 4 turns with same over the cold end of W3
L4 : W5	— 24 turns of 30 SWG and tapped at 3 turns from the cold end
W6	— 4 turns link with 30 SWG over the cold end of W5
L5, L6	— 9³/₄ turns with 30 SWG
L7 : W7	— 2 turn-link with insulated hook-up wire loosely wound over the cold end of
W8	— 10 turns close wound with 30 SWG wire to be slug-tuned
L8, L9	— 10 turns close wound with 30 SWG wire to be slug-tuned
RFC1	— 1mH, RF choke
RFC2	— 100μH, RF choke
RFC3	— 8 turns with 36SWG on TV balun ferrite core
RFC4	— 13 turns with 36SWG on TV balun ferrite core
	— PCB, heatsink for T9, aluminium box for VFO, banana plugs, sockets, earphone plugs, knobs, hook-up wire, shielded wire
RFC5	— 47μH choke

NOTE: L2, L3, L4 are slug tuned and L5, L6 are without slugs.

4. Provides RIT voltage during reception.

Change-over from receive to transmit and vice-versa is completely electronic. It is noiseless, fast and extremely smooth in operation.

The circuit details

Complete circuit diagram of the transceiver is shown in Fig. 2. Variable frequency oscillator (VFO) is a parallel-tuned colpitts oscillator built with n-channel FET BFW11 and is buffered by untuned direct coupled amplifier stages. The stability of the VFO is important for proper operation and styroflex/polysterene capacitors are used to ensure the same. The entire VFO should be housed in a mechanically strong aluminium box to avoid stray interference and render stability.

The tuning and the bandset capacitors C66 and C10 are not easily available in the radio market and a traditional source is the surplus market. They are probably manufactured by BEL. But buying a piece or two from them (if at all possible) shall obviously upset the budget of the total rig!

The VFO with the components as per circuit and the bandset capacitor C10 and coil L1 are set to tune from 3.5 MHz to 3.55 MHz. The quadrupler ahead of the VFO is a class A amplifier with output circuit tuned to the fourth harmonic. It delivers an output in the range of 14.00 to 14.20 MHz which is further distributed to Tx (transmitter) chain through C14 and to pin 10 of detector IC through C15.

The receiver detector is a variation of RX double balanced mixer built around IC1496. In addition to signal from local oscillator, incoming signals through front end band pass filter are also fed to pin 1 of the detector. The resultant audio is amplified by transistor T5 and IC2.

In the transmitter chain, the final amplifier comprises T9 operating in class C. Its output is coupled to antenna through a low pass filter consisting of coils L5, L6 and capacitors C26, C27 and C28. In the control circuit, under key up condition, pin 3 of IC3 remains at 0V. Both D3 and D4 are forward biased and the antenna is connected to receiver input. The RIT transistor T14 remains 'off' and RIT voltage is adjusted by VR3 mounted on the front panel.

At the same time no side-tone is available at the headphone. When the key is depressed pin 3 of IC3 goes up to 2.8V. Both D3 and D4 are reverse biased and the antenna is connected to transmitter output only. The RIT transistor is now 'on' and no adjustable RIT voltage is available during transmission. The muting circuit transistor T12 is also switched on and pin 3 of IC2 is almost at ground potential. Thus no audio output is available from IC2. At the same time keyed +12V DC is available for T7 and T8. Side-tone output is applied to the headphone input simultaneously.

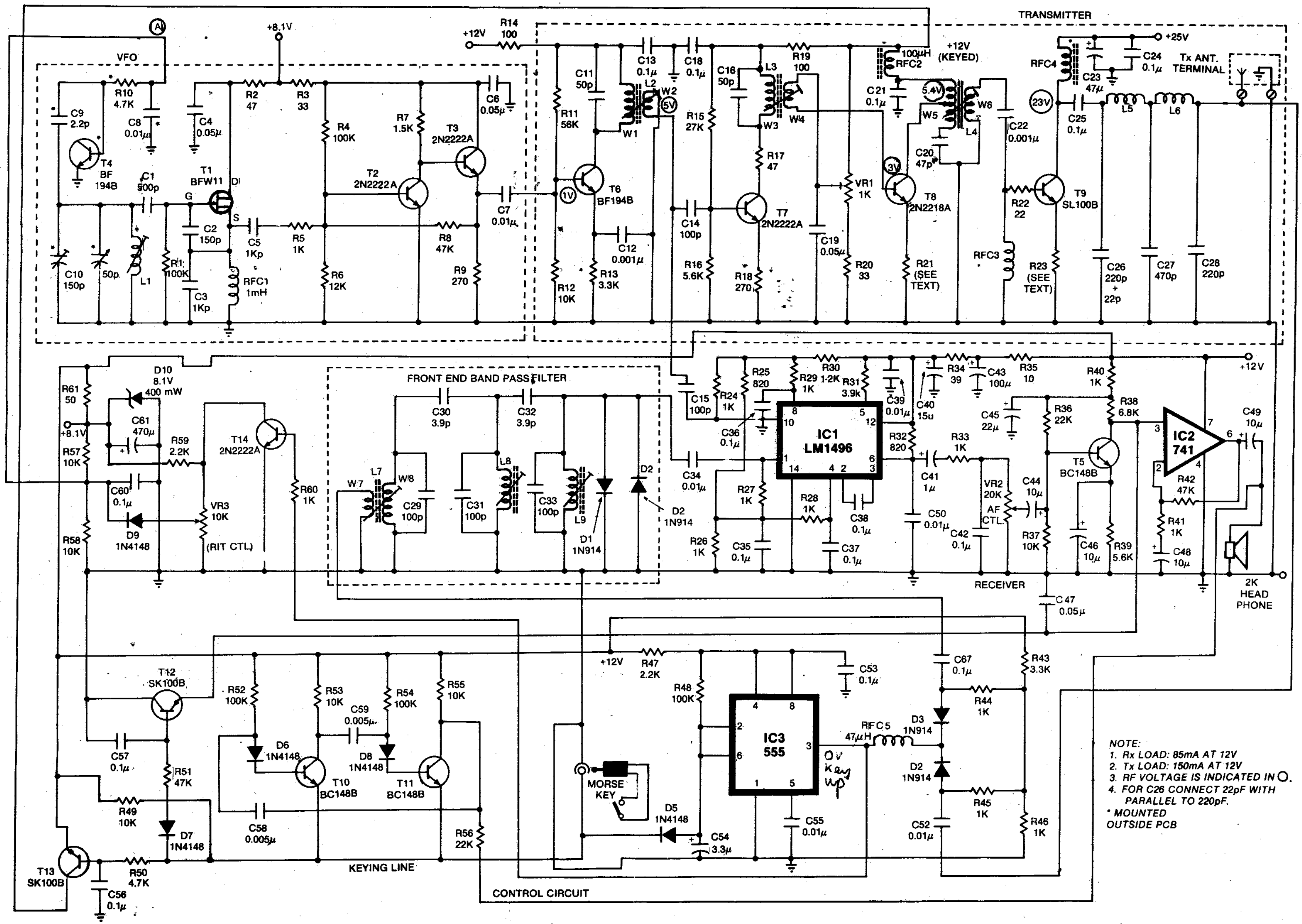


Fig. 2: Complete circuit diagram of the transceiver.

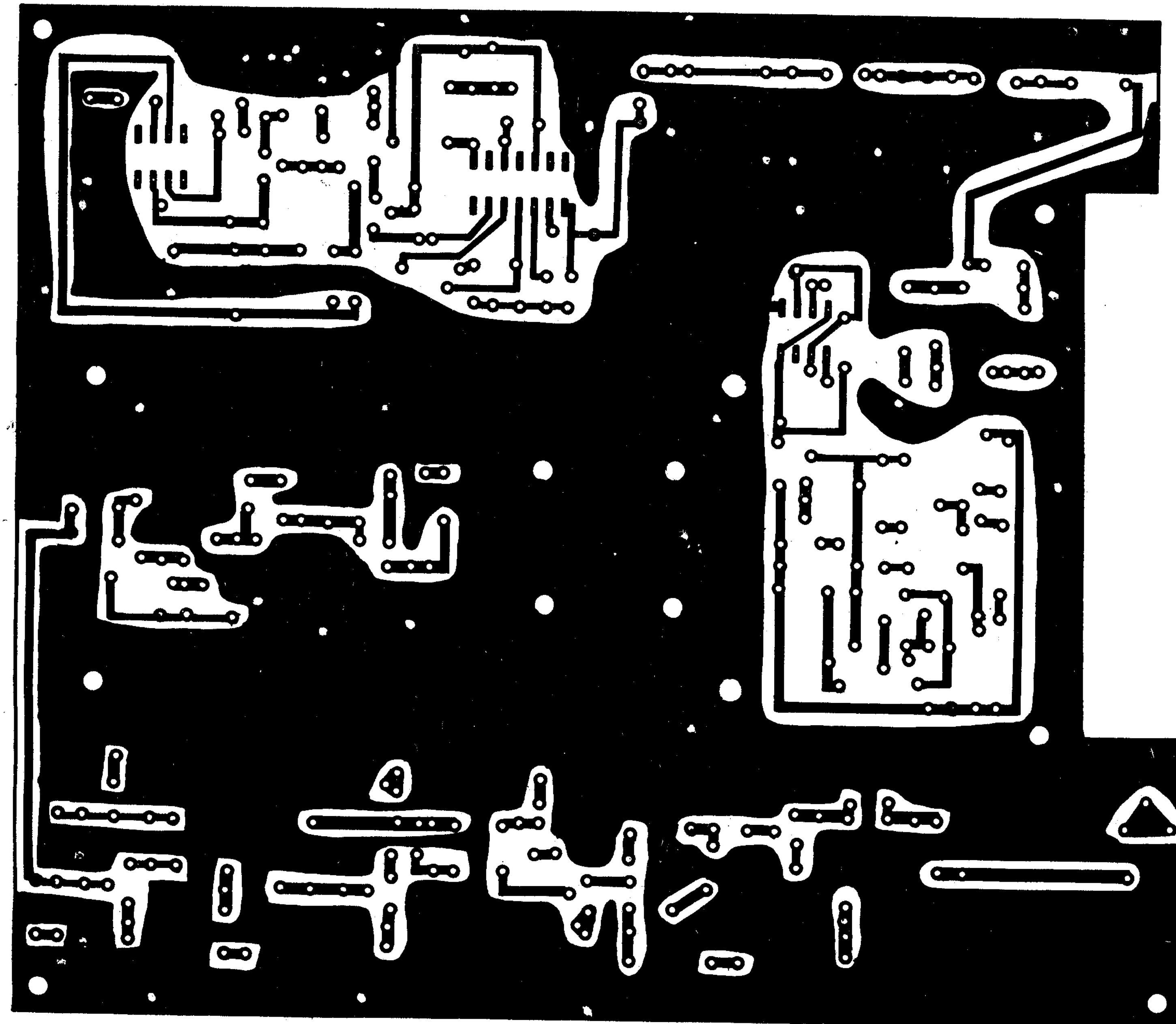


Fig. 3: Actual-size PCB layout of the transceiver. (excluding power supply and RIT section).

Construction

PCB layout for the complete transceiver circuit excluding power supply is shown in Fig. 3. Fig. 4 gives components layout for the same. In addition RIT circuit components are mounted on a small piece of a veroboard. Conventional slug-tuned coils have been used throughout because they are easily available as compared to toroidal ones. A TO-5 type heatsink is required only for the final transistor T9 in the transmitter chain. Sockets have been used for all the ICs. TV balun cores have been used for RFC3 and RFC4. The winding procedure is given in Fig. 7. Unfortunately winding the same number of turns on available balun cores of same dimensions and appearance may provide altogether different results in terms of inductance, Q and frequency response because balun cores being marketed for the same service may vary wildly in characteristics. Cores manufactured by CEL are good for this purpose. The PCB should be accommodated in a home-made aluminium box for proper shielding. However, provide an extra shielding in VFO section for better stability.

Testing and tuning

The following instruments are required for initial testing of the transceiver:

1. Multimeter with RF probe
2. GDO (Gate or grid dip oscillator)
3. Frequency counter
4. A calibrated communication receiver or oscilloscope

In case the constructor does not possess or have access to these instruments, this project should not be attempted at.

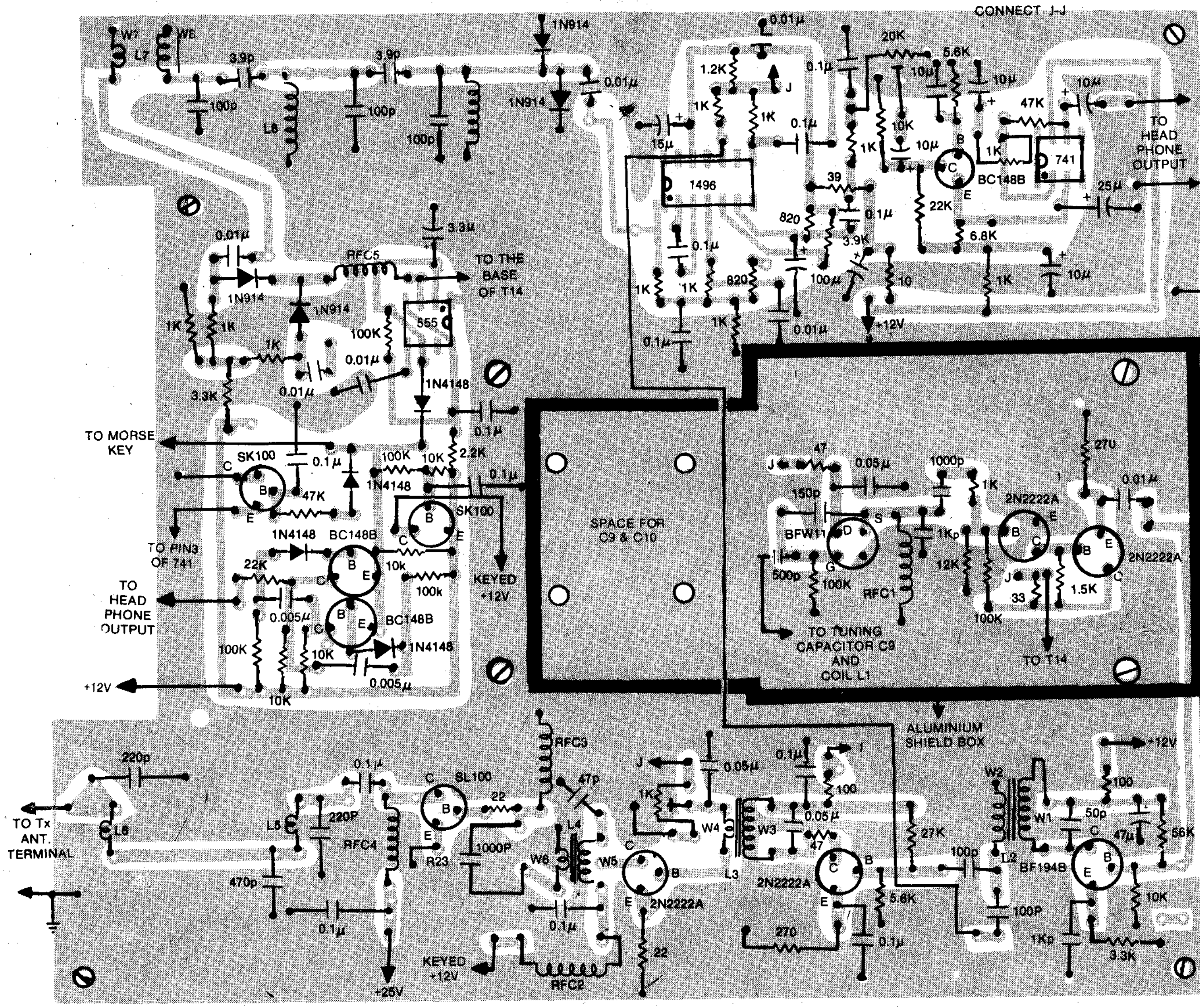


Fig. 4: Components layout for the PCB.

The various DC and RF voltages at different points and under specific conditions are shown in the circuit diagram (Fig. 2). For measuring RF voltage at different points a RF probe may be assembled as shown in Fig. 5 and used with a multimeter. The voltages measured give an idea of comparative RF levels at different stages and they are not accurate or absolute values.

Capacitor C10 and coil L1 are so adjusted that VFO covers a range of 3.50 to 3.55 MHz or so. During reception, the DC voltage at point A for RIT operation varies from 3.4V to 5.1V DC. This variable DC voltage allows a shift of VFO frequency by 600 Hz. The next step is peaking of coil L2 on the transmitter board. The coil is tuned at fourth harmonic of the VFO frequency, so that frequency at pin 10 of detector IC1 varies from 14.0 MHz to 14.20 MHz.

The signal is now peaked by adjusting slugs of coils L7, L8 and L9 of band pass filter. In case of broadcast interference, the slugs are readjusted at the cost of receiver sensitivity. Even with this compromise CW and SSB stations shall pour in under good condition.

To tune the transmitter, the RF input from VFO is disconnected by removing C7 from PCB. The collector current of T8 is adjusted to 30 mA by the preset VR1 under key-down condition. After connecting C7 (VFO output) back to the base of T6, RF voltage is measured across RFC3 under key-down condition. This RF voltage is peaked by adjusting slugs of coils L3 and L4. Apply 25V DC to T9 and connect a 6.3V, 0.3A lamp across antenna terminals as a dummy load. Under keydown condition, this lamp should glow brilliantly. Using a loop probe loosely around the coil L6, the frequency is measured with

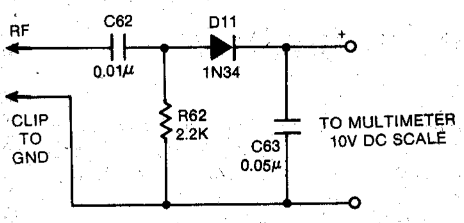


Fig. 5: Circuit diagram for constructing a RF probe.

a frequency counter. The side-tone output is available at the headphone and voltage at pin 3 of IC2 is at a very low level. For R21 and R23 in transmitter circuit author has used a small jumper of 22SWG wire in prototype.

The circuit diagram of the power supply is shown in Fig. 6 and is self-explanatory. A three-terminal 12V regulator IC has been used, current handling capacity of which is improved by the addition of transistor T15. A load current of 1A can easily be handled by this circuit. The 25V DC output can be brought out from the cathode junction of rectifier diodes D12 to D15. The entire circuit has been housed in a standard metal cabinet used for AC voltage stabilisers.

Ordinary dipole antenna fed with twinflex can be used and gives reasonably good results. Dimensions for such an antenna are available in any ARRL/RSGB handbook. However, suggested details are given in Fig. 8. For QRP operation it is advisable not to call CQ, and it is better to answer someone who has just finished calling CQ. As a general practice the front panel RIT control should be set in such a way that the VFO frequency during reception is lowered by about 200 Hz from that during transmission.

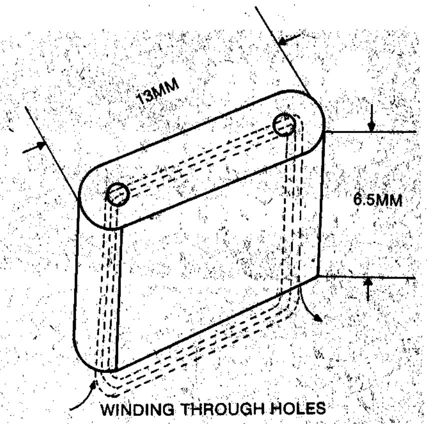


Fig. 7: Winding details on TV balun/core.

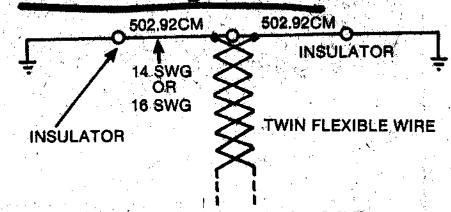


Fig. 8: Suggested antenna for QRP transceiver.

In other words transmission frequency is made to shift slightly on the higher side to zero-beat with the incoming signal. However, it requires some practice to get used to the technique of such transceiving operation.

The prototype has been used by VU2 ATN for more than six months. Its performance has been better than expected. With an output power of less than 2 watts, a number of DX stations have already been worked. The longest DX is LA2AB from Norway with a 559 report for VU2ATN. Russian stations are being worked with consistent good report. A copy of log sheet at VU2 ATN is shown in Table I which gives the reports received with this little wonder. The author is indebted to VU2ALP, VU2APU, VU2CZ, VU2ARQ, VU2RCH and many others who have inspired and helped him in constructing and testing this QRP equipment. □

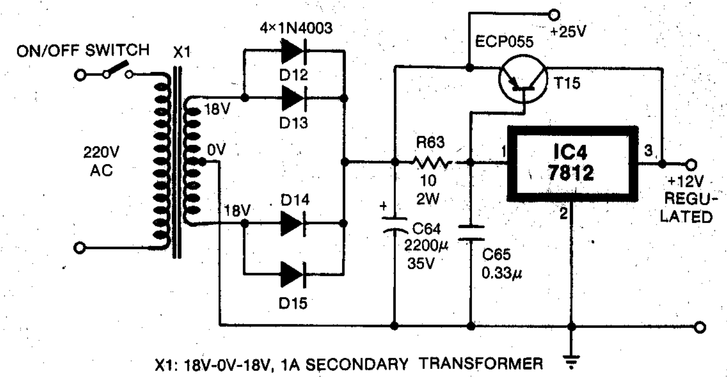


Fig. 6: Circuit diagram of regulated power supply.

TABLE I

DATE/TIME I.S.T.	STATION WORKED	HIS RST	RST RECVD	HIS NAME	HIS QTH	FREQ	MODE OF WORKING	TIME OF ENDG.	REMARKS
7.2.87 0933	UL7GDX	579	579	OLEG	ALMA ATA	14	2×CW	0942	
14.2.87 0918	UM9 NWA	599	589	ALIK	OSH	"	"	0929	
1521	VU2SRB	59	599	SUDHIR	NAGPUR	"	SSB/CW	1531	
21.2.87 1624	RZ4HZZ	599	599	SERGEY	KUIB-SHEIV	"	2×CW	1632	
7.3.87 0849	VU4 APR/RBI	569	559	BHARATHI	ANDAMAN IS	"	"	0855	Special operator from Andaman Island.
10.3.87 1950	SM4EMO	599	559	KEN	KUMLA	"	"	1957	
13.3.87 1947	LA2AB	589	559	OLAV	OSLO	"	"	1955	
16.3.87 0820	UI8AH	599	599	TOL	TASHKENT	"	"	0828	
28.3.87 1750	RA9JM	599	599	OLEG	SAMOTLOR	"	"	1756	
7.4.87 2048	OH2 BMM	549	539	PENTI	HELSINKI	"	"	2101	
17.4.87 2116	SLφCB	599	579	HANS	STOCKHOLM	"	"	2128	

2016

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RF TO DC CONVERTER

Table of Contents

Abstract

RF to DC Converter is a component of a wireless power transfer system. This component will harvest Radio Frequency (RF) energy and convert that energy to Direct Current (DC). The wireless power transfer system is being designed to operate at a frequency of 5.8 GHz. The RF to DC converter is a passive device that utilizes diodes. The only outside energy that this system will receive is the RF energy that is harvested by its receiving antenna.

Acknowledgements

A special thanks to Dr. Prasad Shastry for all of the help and guidance he has provided throughout this project.

Chapter 1. Introduction

Wireless power transfer systems are the next big innovation in mobile devices. This technology will allow for users of mobile devices to be free from the wires that are currently being used to charge these devices. The RF to DC converter will allow for a wireless power transfer system to convert the captured RF energy to a usable DC output.

The first aspect of the project is the literature review. Through research, several changes had to be made to the preliminary design of the converter.

The design process is the next phase of the RF to DC converter project. Each component of the project has to be designed in Advanced Design System (ADS), a high frequency computer-aided design and simulation software. Using ADS, each component is designed and redesigned independently even though all components are actually co-dependent upon one another and must be designed accordingly.

Once all components have been designed, simulations determine whether or not the component is working. ADS has a very good simulation program, allowing the RF to DC converter project to be accurately simulated before manufacturing the printed circuit board. The manufactured board can then be used for circuit assembly and testing. Each component that is not a microstrip has to be soldered onto the printed circuit board. When the circuit has been assembled, it is ready for testing.

The RF to DC converter is tested on its own and in a wireless power transfer system. This system consists of all components present in the block diagram (Chapter 3) and models a real world scenario of how this system may be used.

The possible real world applications for this project are endless. While focus has been placed on near-field wireless power transfer systems, such as pads that have the capability of

charging a cellular phone when the phone is placed on it, this project's applications are more contained within the idea of far-field wireless power transfer systems. This, for example, could be a charger that wirelessly charges a cellular phone from a given distance. However, very little focus has been placed on these applications in industry. This project, though, is moving forward in this direction, showing its significance in a narrow but growing field.

Chapter 2. Literature Review

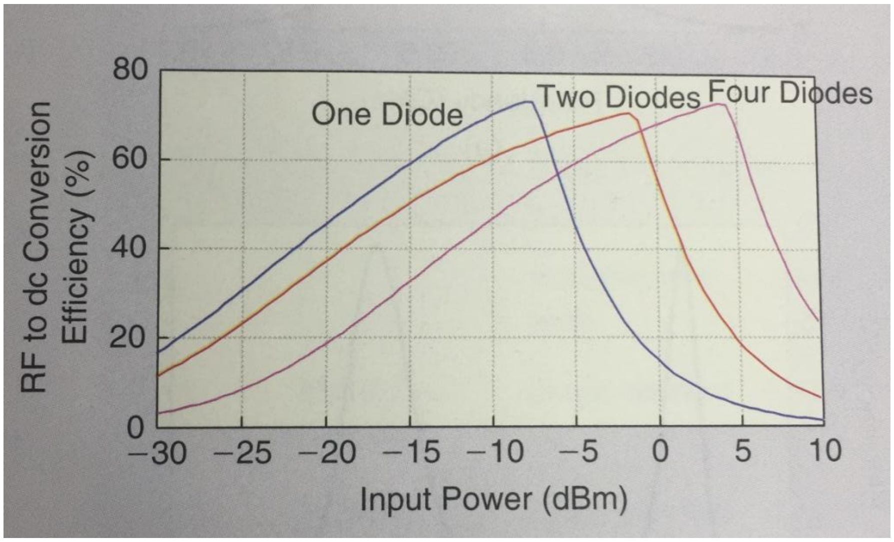


Fig. 1 Efficiency of Full Wave Rectifiers vs Input Power [1]

Fig. 1 from [1] shows that there are numerous options for rectifying RF signals. In theory, it is expected that, the higher the number of diodes, the more efficient the system is. Therefore, it would be expected that the four diode system would be more efficient than the two diode system. For lower power level received, though, this appears to not be the case. Fig. 2 gives a description of the four diode full-wave bridge rectifier. Fig. 3 shows the two diode full-wave rectifier.

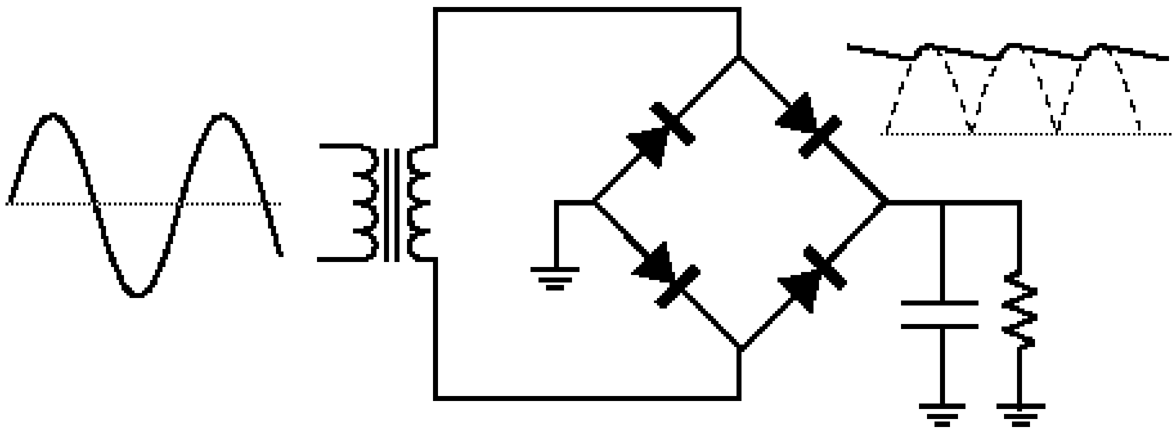


Fig. 2 Four Diode Full-Wave Bridge Rectifier

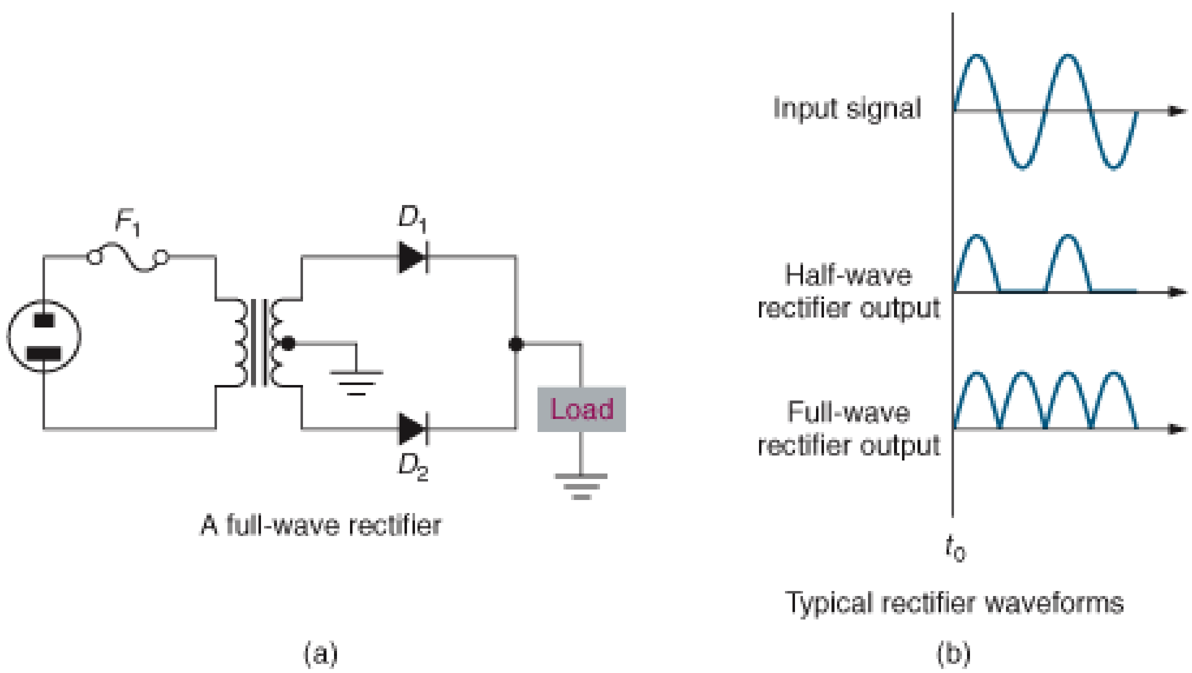


Fig. 3 Two Diode Full-Wave Rectifier

Wireless power transfer systems are not a new idea. Engineers have been trying to harness this technology for years, but there are many challenges that need to be overcome [2].

The first issue is efficient power reception. In order to receive the power efficiently the impedance of the rectifier must be matched to a receiving antenna over a wide range of frequencies. The power that is expected to be received by the antenna is also going to be extremely low, so a high gain antenna is most likely necessary in order to have enough input power in the system.

The issue with wireless power transfer systems is in fact the efficiency at which they operate [3]. The design in [3] was designed to operate at 2.45 GHz, which is in a different ISM band than the one being used in this project, but it gave a good baseline for efficiency expectations. The design in [3] was able to transmit power of 20dBm over a distance of 1 meter at an efficiency of 56%. Once the signal was rectified, the total system efficiency from transmitter to DC output was 19%. These results were also found in [4]. This gave consistency for what is expected of a RF to DC converter system.

This project has to implement a balun in order for the diodes to function out of phase from one another. The balun for this project was designed based off of the information found in [5]. With a little trial and error to maximize efficiency, the balun has been implemented into the system and functions well.

The project in [6] is perhaps the most closely related project to this one, consisting of two portions. The first was the design of a wireless power transfer system operating at a frequency of 915 MHz and being built out of commercially available parts. The second was the design of a rectenna system functioning at a frequency of 5.8 GHz, integrating a rectifier and antenna together. This rectifier system is exceptionally important when referring to this project due to the fact that this is the main focus of the project, making it a continuation of the original project described in [6].

Chapter 3. Functional Description

3.1 Introduction

This section will discuss the overall function of the RF to DC converter.

3.2 Block Diagram

This project focuses on converting RF energy to DC energy as efficiently as possible. The converter that this project uses will be in the receiving block of a wireless power transfer system. While design work has been done mainly for the converter, a full transmitting system and the rest of the receiving system is designed as well. This will allow for the converter to be tested in a wireless power system.

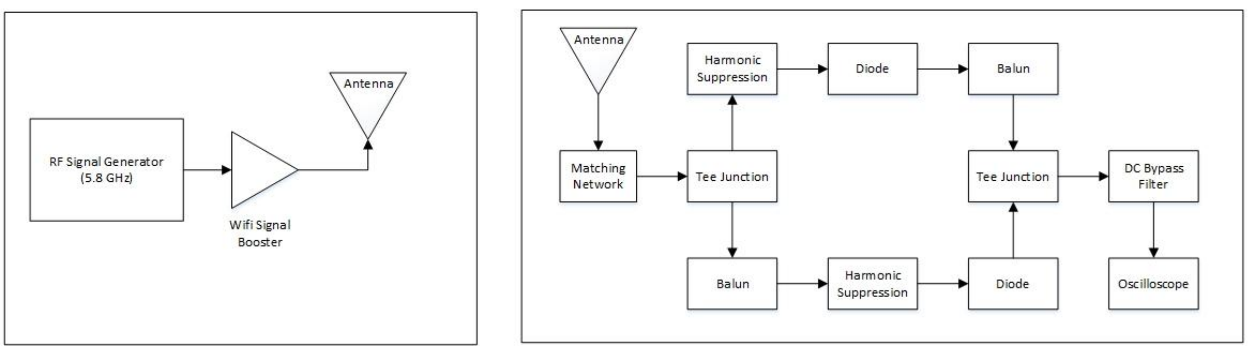


Fig. 4 Block Diagram of Wireless Power Transfer System. Transmitting Block on left and Receiving Block with RF to DC Converter on right

Fig. 4 shows both the transmitting block and the receiving block of a wireless power transfer system with RF to DC conversion, on the left and right of the diagram, respectively. Together, this system is designed specifically to function at 5.8 GHz and can function at variable distances between the transmitting and receiving antennas.

The transmitting block is composed of three components. The first is a Hewlett Packard 8260C sweep oscillator, labeled as RF Signal Generator in Fig. 4. This device can be used to

generate the 5.8GHz signal that will be transmitted. The sweep oscillator has a variable amplitude for the generated signal. The output amplitude of the sweep oscillator ranges from -1 decibel-milliwatts (dBm) to 16.25 dBm, which can be measured using a spectrum analyzer. The next component in the transmitting block is a Sunhans WiFi signal booster, labeled as the WiFi Signal Booster in Fig. 4. This product is designed to amplify WiFi signals between 5 and 5.8GHz from their standard amplitude (0-20 dBm) to 33 dBm. This is important due to the fact that, for this project, the transmitted power must be as high as possible. This product will amplify the signal from the sweep oscillator from 16 dBm to 33 dBm. The next component of the transmitting block is a L-com 19 decibel relevant to isotropic gain (dBi), narrow beam antenna. This antenna is a necessity at the transmitting end of the system due to the losses encountered in free space. With such a high fundamental frequency (5.8 GHz) the transmission losses through free space are going to be extremely large. In order to reduce these losses, high gain transmitting and receiving antennas are a necessity.

The receiving block of Fig. 4 is composed of two components. The first is a receiving antenna. There are two choices that can be used for the receiving antenna. If the received power is considered to be too low, the same L-com 19 dBi gain, narrow beam antenna can be used to harvest additional RF energy. If the received power is adequate, a Sunhans 6 dBi gain omnidirectional antenna can be used. This antenna will not be able to harvest as much RF energy, but it is much more compact and practical for commercial applications. The second component of the receiving block is the RF to DC converter that is being designed in this project. Each component of the RF to DC converter will be discussed in more detail in the following chapter.

3.3 Conclusion

The block diagram for the RF to DC converter project is a good starting point for understanding how the RF to DC converter works within a wireless power transfer system. Chapter 4 will discuss the design of the RF to DC converter system.

Chapter 4. RF to DC Converter Design

4.1: Introduction

This section will cover the individual components that make up the RF to DC converter and provide detailed descriptions of each. Each component is designed individually, but each system is codependent on the others. When a change is made to one component, changes have to be made to all additional components to compensate.

4.2: Diode Configuration

The first aspect of design that had to be considered in this project was how the diodes would be configured. There are multiple ways to design a full-wave rectifier. In this project there were two options to choose from; a two diode design and a four diode design, seen in Fig. 3 and Fig. 2, respectively. In this project a two diodes are used due to the fact that it was found to be more efficient. The two diode design ultimately dictates the overall size of the circuit as well. Each diode has its own branch in the design, which has a component of all other design components that are implemented in this project.

4.3: Matching Network

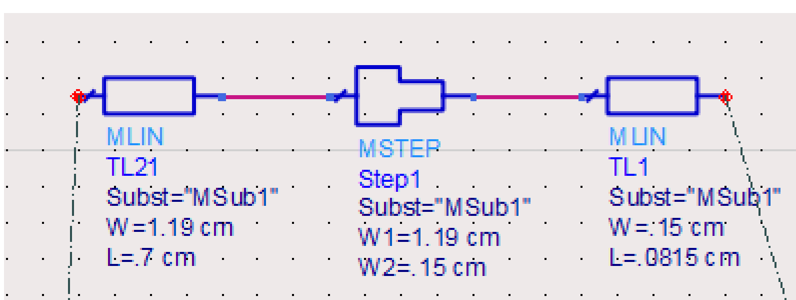


Fig. 5 ADS Schematic Design for Impedance Matching Network

A matching network is designed to match the impedance of the rectifier to standard impedance of a connector. In this project, the matching network is designed to match the

impedance of the converter to 50 ohms. 50 ohms is a standard impedance used in radio frequency engineering practice and will be the impedance of the coaxial cable adapter that will be connected to the input of this component. This will help to maximize the efficiency of the system.

The matching network has to be the last component designed, because the impedance of the system changes as other components are changed. In order to accurately match the impedance of the system, the matching network has to be the last component to be designed. This matching network takes on a couple forms in this project. The first of these forms is a quarter wave transform to match the impedance of the system to 50 ohms. The results obtained from this will be discussed in chapter 5.

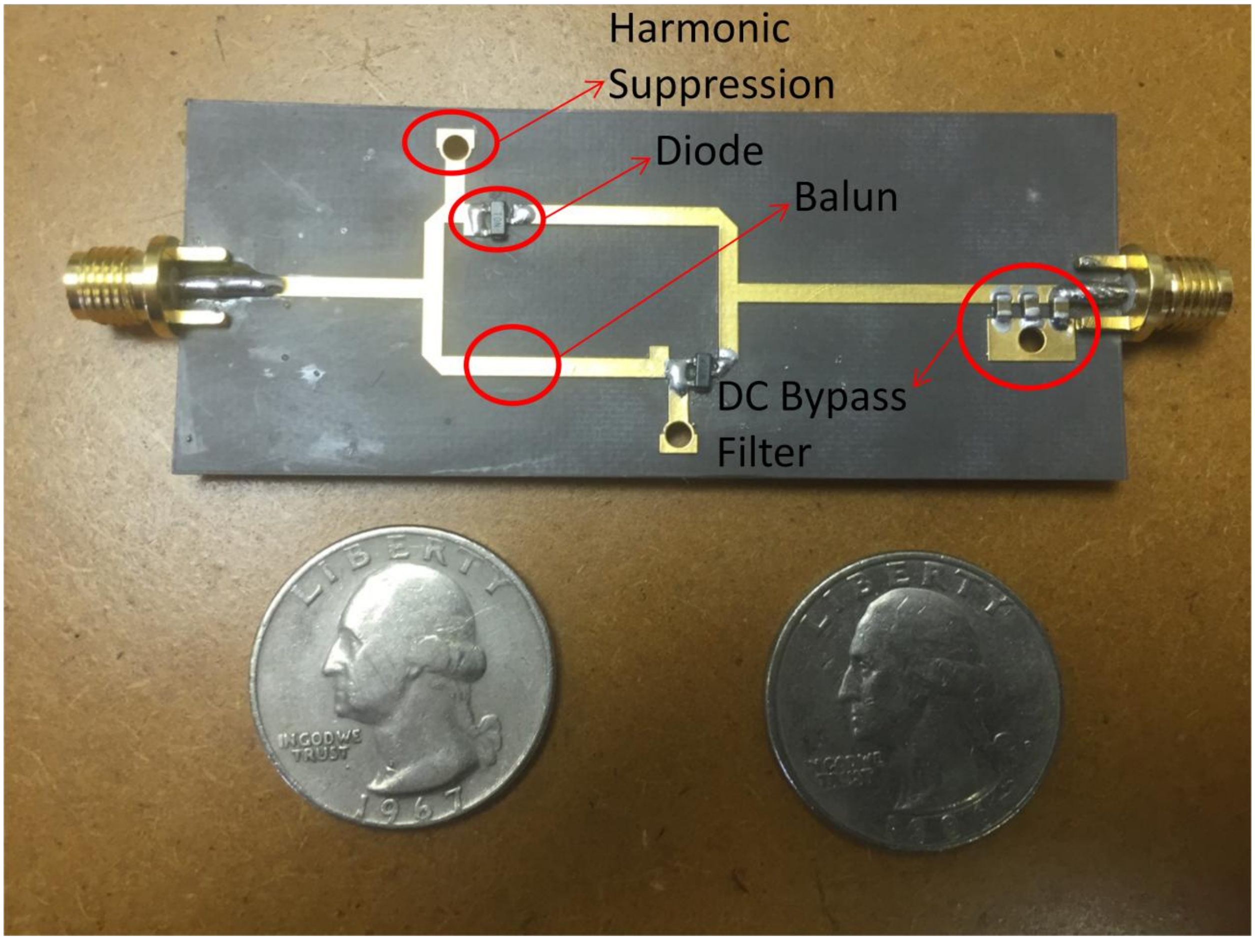
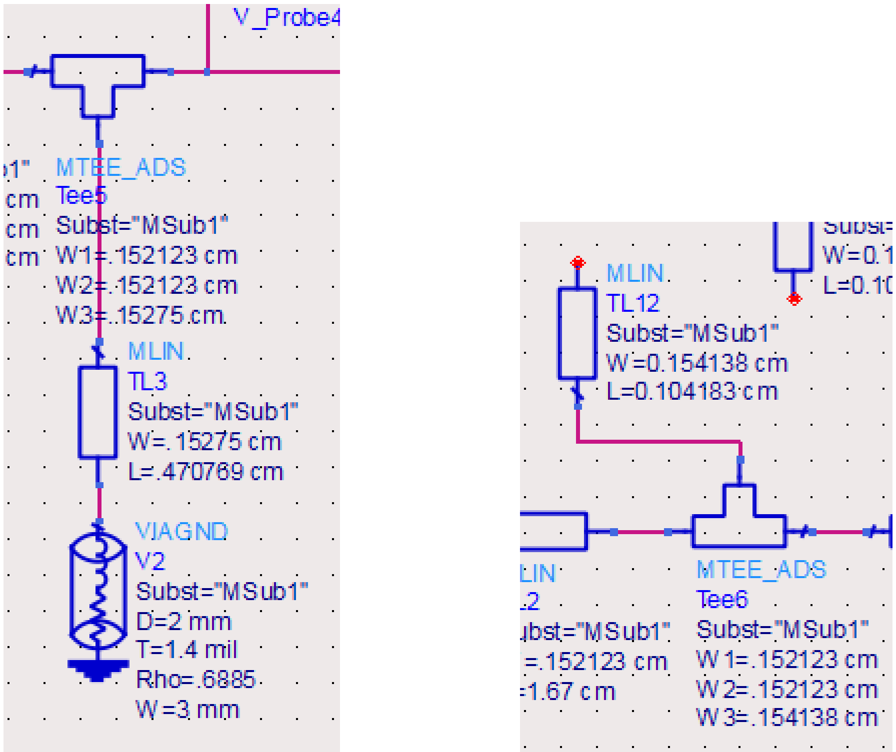


Fig. 6 RF to DC Converter (unmatched)

The second form that is applied and tested in this project is having no matching network at all. For a majority of this component design there was simply a 50 ohm 180 degree phase shift line being used as a placeholder as seen in Fig. 6. The far left microstrip connected to the SMA adapter is the placeholder line. The quarters in Fig. 6 are used as a reference to show the size of the physical component, coming out to about 3 inches long by 1 inch tall. Each of the individual components labeled in Fig. 6 will be discussed in detail later in this report.

The simulation results for the system using only the placeholder line are extremely promising. For this reason, the system using the placeholder line is manufactured along with the system using the matching network. The simulation results will be discussed later in the report.

4.4: Harmonic Suppression



(a) (b)

Fig. 7 (a) ADS Schematic of Second Order Harmonic Suppression; (b) ADS Schematic of Third Order Harmonic Suppression

In this project, harmonic suppression stubs are used as the input filter. The diodes will generate harmonics when they are active. Harmonic frequencies are unwanted signals generated by the diodes. These harmonics are generated and transmitted in both directions from the diodes. If these harmonic signals reach the receiving antenna of the system they will be radiated in space. To prevent these signals from reaching the transmitting antenna, the converter was designed with harmonic suppression stubs. These stubs, as seen in Fig. 7, are designed to suppress the second and third harmonic frequencies. These are the only harmonics that had high enough power levels to warrant a suppression. The harmonics will be at frequencies of twice the

fundamental frequency, three times the fundamental frequency, etc. These harmonics have low power levels.

4.5: Diode

The diode selected in this project is the HSMS-2860 Schottky detector diode from Digikey. This diode is used in several of the projects that were used as research tools in this project. This was also the diode that was used in previous projects of similar type done at Bradley University [6]. This diode was also perfect for use in this project because it had a pSpice file readily available, allowing for quick and accurate simulation results. Once this diode was applied to simulation the results were promising; therefore, there was no further discussion on whether another diode would be used.

4.6: Balun

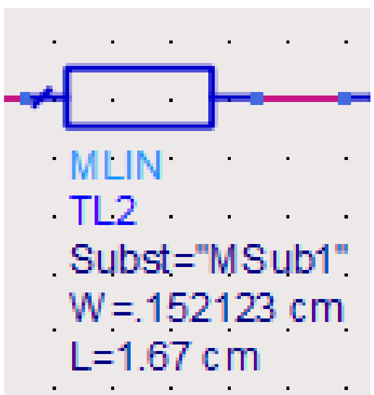


Fig. 8 ADS Schematic Design of Balun

The balun is one of the key components of the RF to DC converter project due to the fact that it allows the diodes in the system to function out of phase from one another. In order for a full-wave rectifier to function properly, one diode must be "on" while another is "off". In this system, the diodes will only be active when the incoming signal is high, or a positive voltage. In order for the system to have at least one diode on at all times, one diode would have to receive a

positive voltage while the other receives a negative voltage. This would imply that the diodes are receiving signals that are 180 degrees out of phase of one another. In order to do this, a balun is placed before one of the diodes to shift the signal being received by that diode by 180 degrees.

4.7: DC Bypass Filter

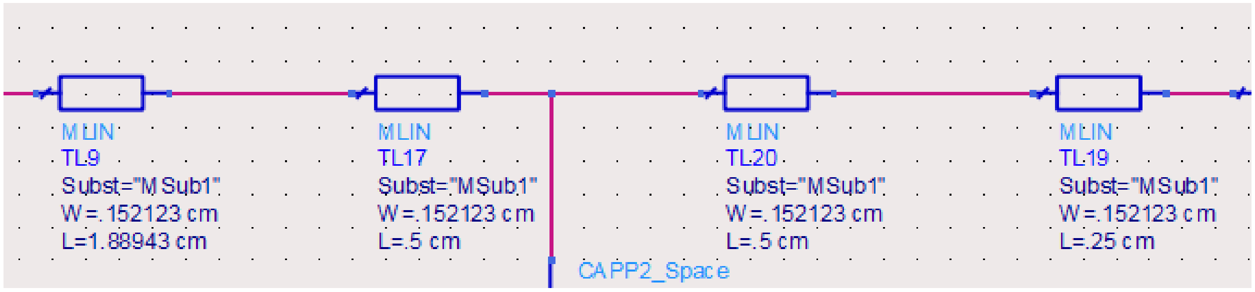
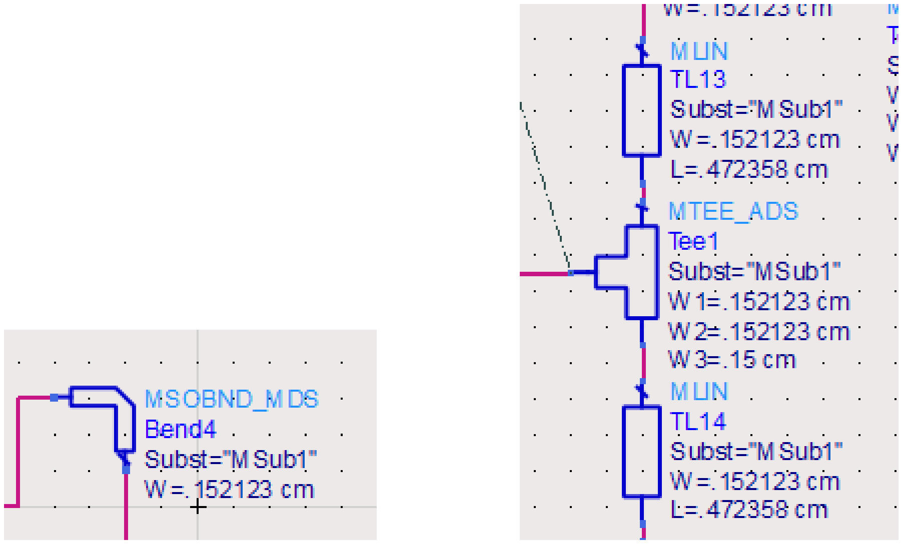


Fig. 9 ADS Design of Output Microstrip Spacing

The output of this system has to be filtered. The goal of this filter, though, is different than the input filters. While the input filter only suppresses the signals that are generated at the harmonic frequencies, the output filtering is designed to suppress all signals that are not DC. The most efficient output filtering technique found through simulations was a DC bypass filter. Fig. 9 shows several microstrips placed one after the other. At each of those intervals a capacitor will be soldered to ground. These capacitors will then run the higher frequency signals to ground and will allow the DC component of the signal to pass through. With several capacitors running the higher frequency signals to ground, this will allow for a smooth DC output from the system.

4.8: Discontinuities



(a) (b)

Fig. 10 ADS Schematic of Discontinuities Present in RF to DC Converter Project (a) Schematic Bend (b) Schematic Tee-Junction

Discontinuities in layout are inevitable in this project. In order to provide the most accurate simulation results possible, it was necessary to implement discontinuities in the schematics in order to accurately simulate the converter schematic as a whole. Discontinuities are inevitable in design of printed circuit board, so they must be accounted for in simulation as well. Discontinuities will give inefficiencies and alter the design of other components, such as the balun and matching network. These discontinuities also allow for accurate generation of necessary layouts. Without these discontinuities to connect the microstrip lines, the layouts would not be a continuous circuit.

4.9: Conclusion

All of the design components of this system come together to make the entire layout of the system. Chapter 5 will now discuss the simulation results of the layout.

Chapter 5. Simulation Results

5.1: Introduction

This section discusses the simulation results of two different designs that were produced in attempts to maximize efficiency. The first was designed by putting a placeholder line at the input of the system. The second was designed with a quarter-wave matching network at the input.

5.2: Unmatched Converter

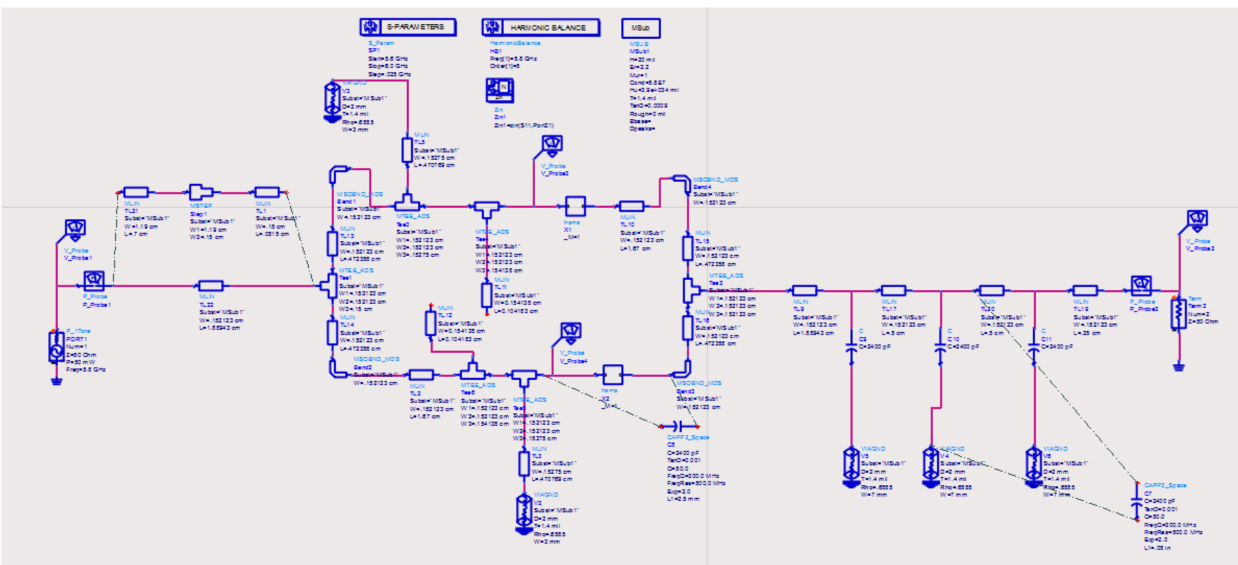
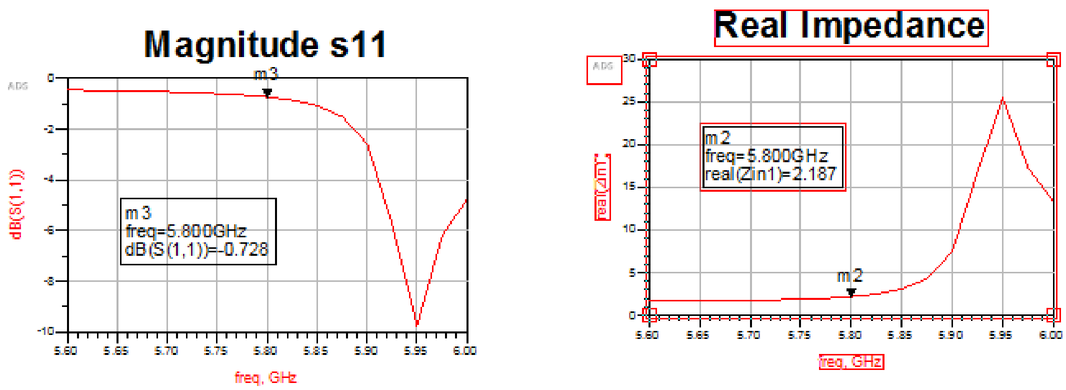


Fig. 11 ADS Schematic Design for Simulation of Unmatched Converter

Fig. 11 shows the ADS schematic designed to simulate the unmatched input design for the RF to DC converter. This schematic has all parts included in the design portion of this report (chapter 4) along with a few simulation parameters necessary to test the schematic. This schematic was tested with no input matching network connected at the input. With no matching network, this system gives a good baseline test for the project. The input, in theory, should

always be matched to what it is being connected to. In this case, the input should be matched to 50 ohms. Refer to the appendix for printed circuit board information.



(a) (b)

Fig. 12 ADS Simulation Results for Unmatched Converter. (a) Magnitude of Reflection Coefficient seen at input. (b) Real Impedance seen at input

From simulation results seen in Fig. 12, there is by no means a match to 50 ohms. The impedance of the system seen at the input of the unmatched network is 2.187-j10 ohms. Theory states that if a system is not matched to the impedance of the source it is receiving signal from, it will reflect a great deal of the signal it is supposed to receive and ultimately have poor efficiency. Fig. 12(a) shows that the reflection coefficient is also very high. The ideal reflection coefficient should be in the -30 and lower dB range.

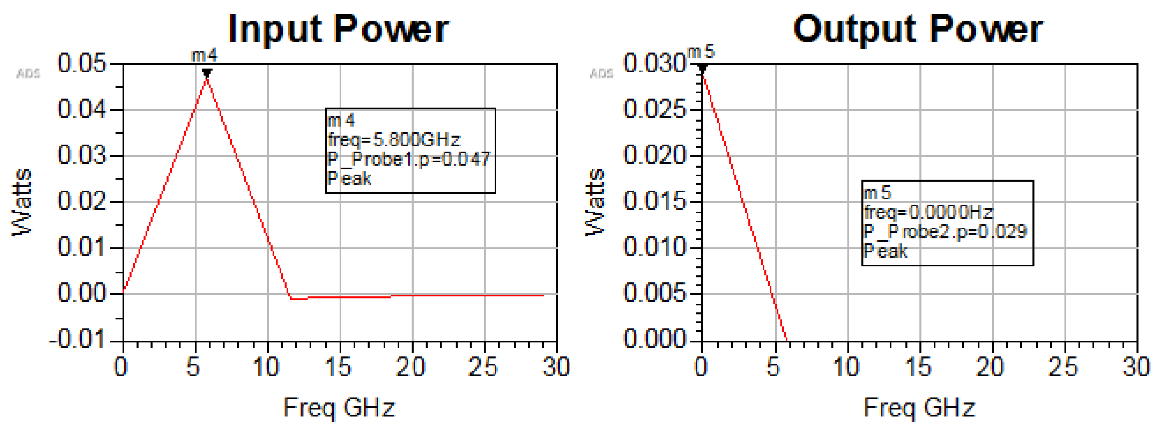


Fig. 13 Input Power vs. Output Power of unmatched converter ADS Schematic Simulations

The power input to the system for simulation purpose was 50 milliwatts (mW) at 5.8GHz from a generator that has a reference impedance of 50 ohms. The simulation results from Fig. 13(a) show that the system is receiving 47 mW, which would mean that only 6% of the power that is at the input of the system is reflected and the rest is taken into the system. This does not coincide with theory, but the results are phenomenal. The output power of the system seen in Fig. 13(b) shows that the output DC power of the system is 29 mW. These simulation results then show that the system receives almost all of the power that is available and operates at 61.7% efficiency. From literature review, the system goal was to eclipse 50%, so a system operating at 60% or more well exceeds project goals.

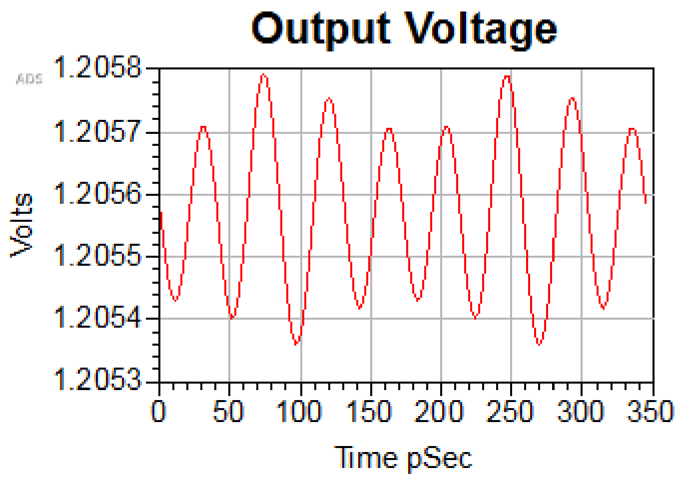


Fig. 14 Output Wave Form for ADS Schematic Simulation of unmatched converter

The output voltage of the unmatched converter is almost completely flat. For this project, ripple in the output waveform must be kept at a minimum in order for devices to be able to harness its output as DC. The ripple in this output is far less than the desired 1% that was originally stated as a specification of the project, as can be seen in Fig. 14. To calculate this, the peak-to-peak difference is calculated to be .0005 volts (V). This value is divided by the average voltage of the signal. This was 1.20555 V. In practice, if there is a lot of ripple at the output, there can be more DC bypass capacitors added to the output to reduce ripple. If the DC output has too much ripple it could damage the device that it is charging. The output here, though, is calculated to be hundredths of a percent.

5.3: Matched Converter

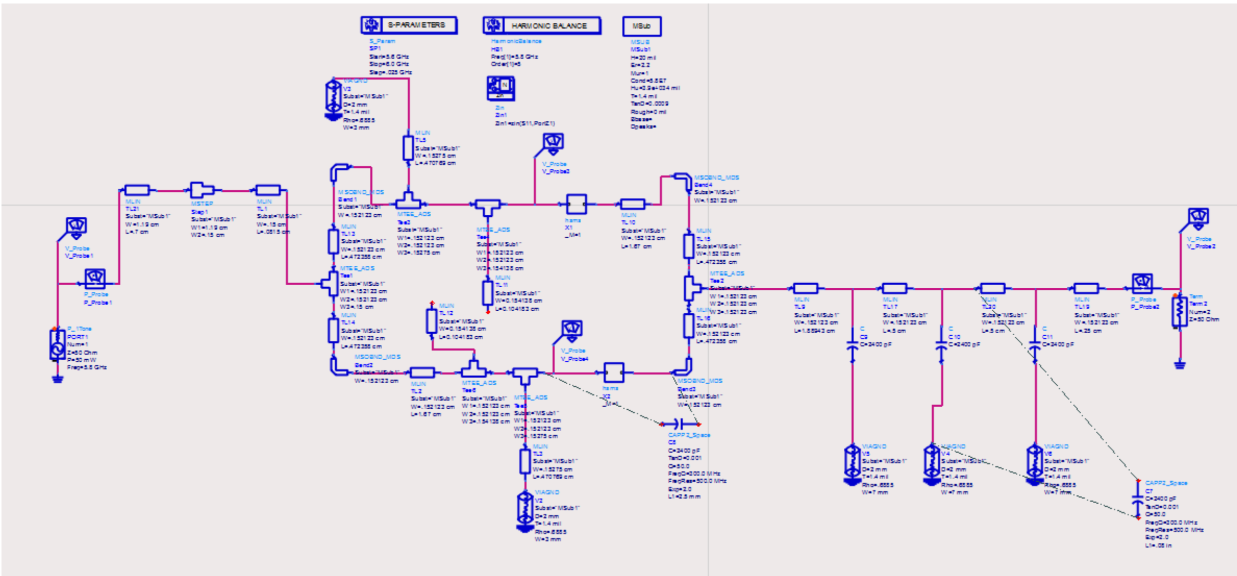
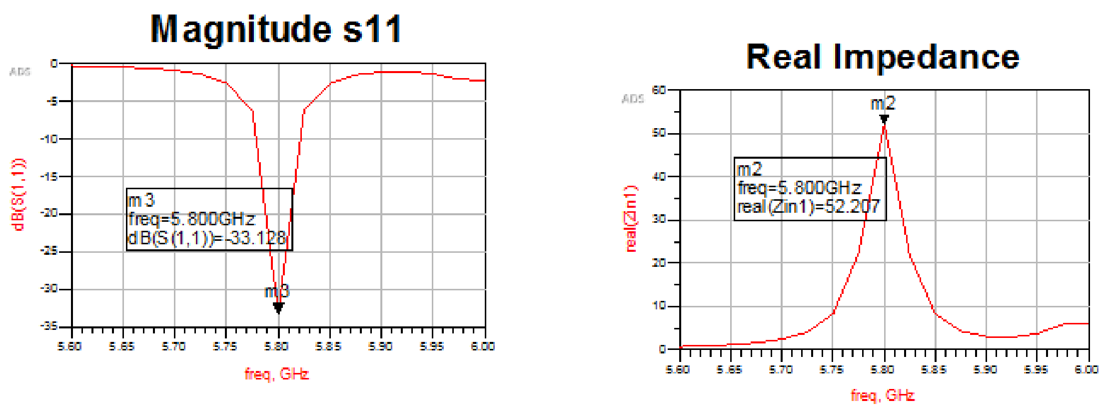


Fig. 15 ADS Schematic Design for Simulation of Matched Converter

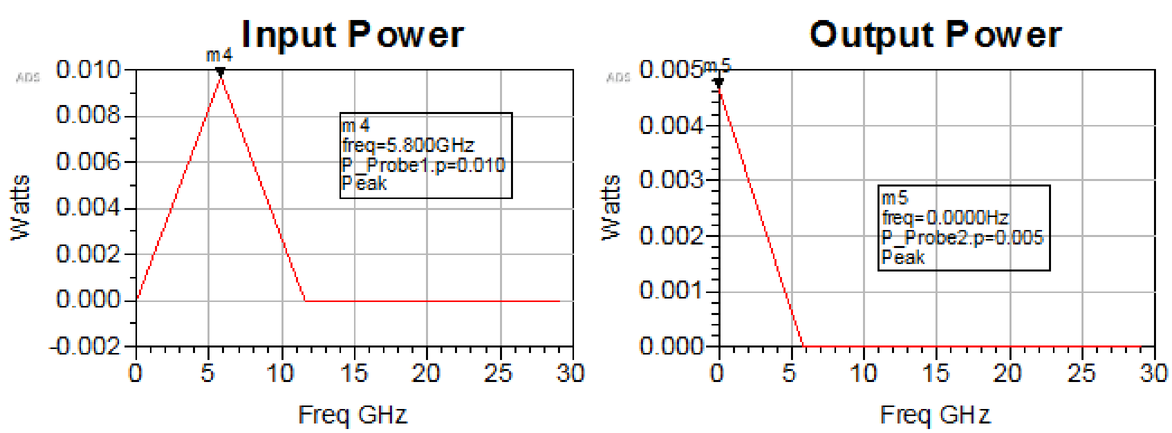
Fig. 15 shows the ADS schematic used to simulate the matched converter design for the RF to DC converter project. The matched converter has the matching network implemented as opposed to simply having the microstrip line placeholder. This design is what theoretically should give the best results possible for the RF to DC converter. Since the input is matched very closely to 50 ohms, the system should receive the maximum power possible.



(a) (b)

Fig. 16 ADS Simulation Results for Matched Network. (a) Magnitude of Reflection Coefficient Seen at Input. (b) Real Impedance Seen at Input

The simulation results seen in Fig. 16 show that the impedance matching network is working extremely well for what it was designed for. The input impedance is matched now to 52 ohms while the magnitude of the reflection coefficient is extremely low at the input. This, in theory, will give the best test results and allow for the system to operate at its full potential.



(a) (b)

Fig. 17 Input Power and Output Power of Matched Converter ADS Schematic Simulation

Fig. 17 shows the simulation results for power input and output of the design with the matching network implemented. These results are not nearly as good as the results obtained with the unmatched input. The input seems to only be receiving 20% of the power available from the generator, which means that it is reflecting 80% of the power back. This gives high inefficiency and does not allow for the system to operate well. Since the input power is so low, the system is operating less efficiently than in the unmatched case. The unmatched case has an efficiency of 61.7% while the matched case has an efficiency of 50%. These results are not necessarily promising, but they are founded in sound logic and good engineering practice. For these reasons, this design was also pursued.

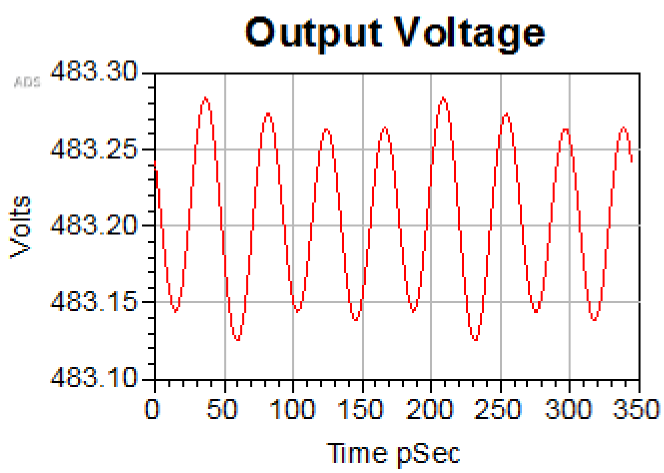


Fig. 18 Output Wave Form for ADS Schematic Simulation of Unmatched Converter (Voltage in mV)

The output voltage of the matched converter is almost completely flat, similar to the output voltage of the unmatched converter. For this project, ripple in the output waveform must be kept minimal in order for devices to be able to harness its output as DC. The ripple in this output is also far less than the desired 1%. To calculate this, the peak-to-peak difference is calculated to be .0002 V. This value is then divided by the average voltage of the signal, which is .4832 V. In practice, if there is a lot of ripple at the output, there can be more DC bypass

capacitors added to the output. This will reduce ripple. Again, if the DC output has too much ripple, it could damage the device that it is charging.

5.4: Conclusions

The simulation results of the two converters give very different results. Chapter 6 will discuss the design implementation and testing results of these two converters.

Chapter 6. Design Implementation & Test Results

6.1: Layout Implementation

Only one circuit is designed and completely fabricated. This is the unmatched converter. Fig. 6 shows the circuit board that was manufactured for the RF to DC Converter project. This component is small in size, less than 3 square inches. Microcircuits Inc. manufactured the circuit boards and each component is soldered onto the board in order to create a finished product. The soldered components consist of the diodes, capacitors, and SMA adapters at the input and output. Major design components are highlighted in red in Fig. 6.

6.2: Test Results

The testing done for this project is minimal due to time constraints. Currently, the best test results obtained include the overall power transferred at a frequency of 5.8 GHz and a verified DC output from the RF to DC converter.

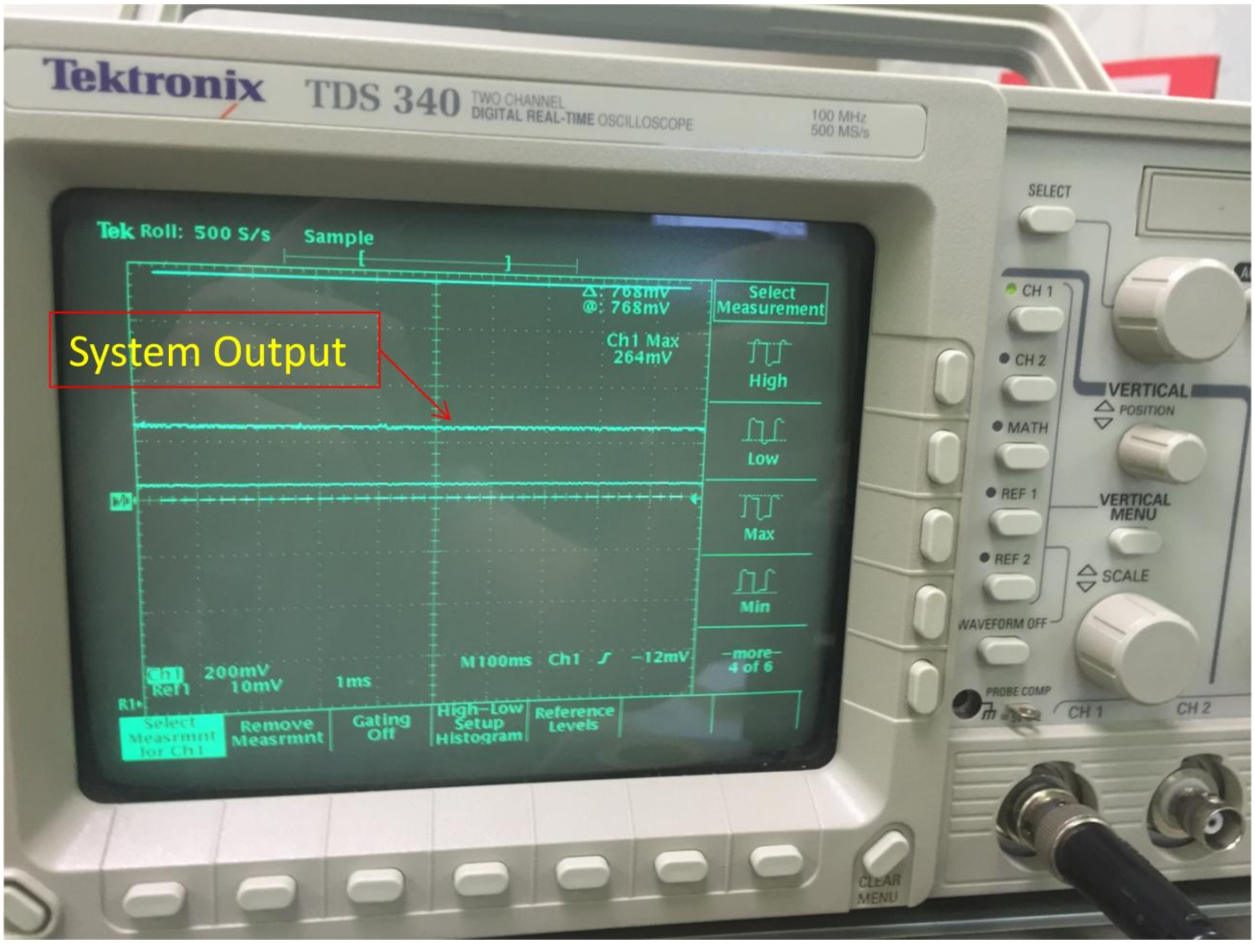


Fig. 19 Time Domain DC output of the RF to DC Converter Project

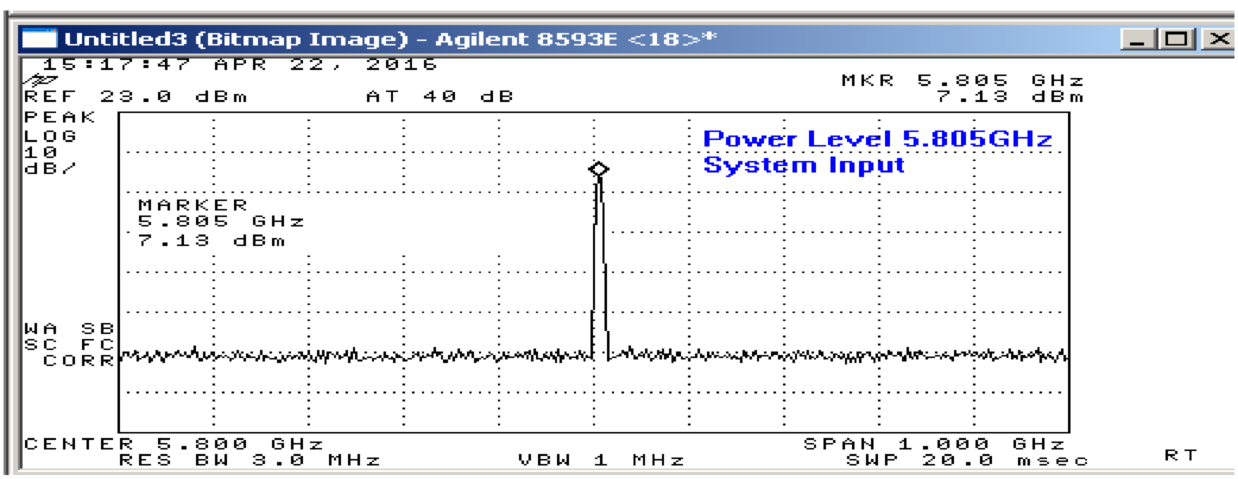


Fig. 20 Input Signal to RF to DC Converter

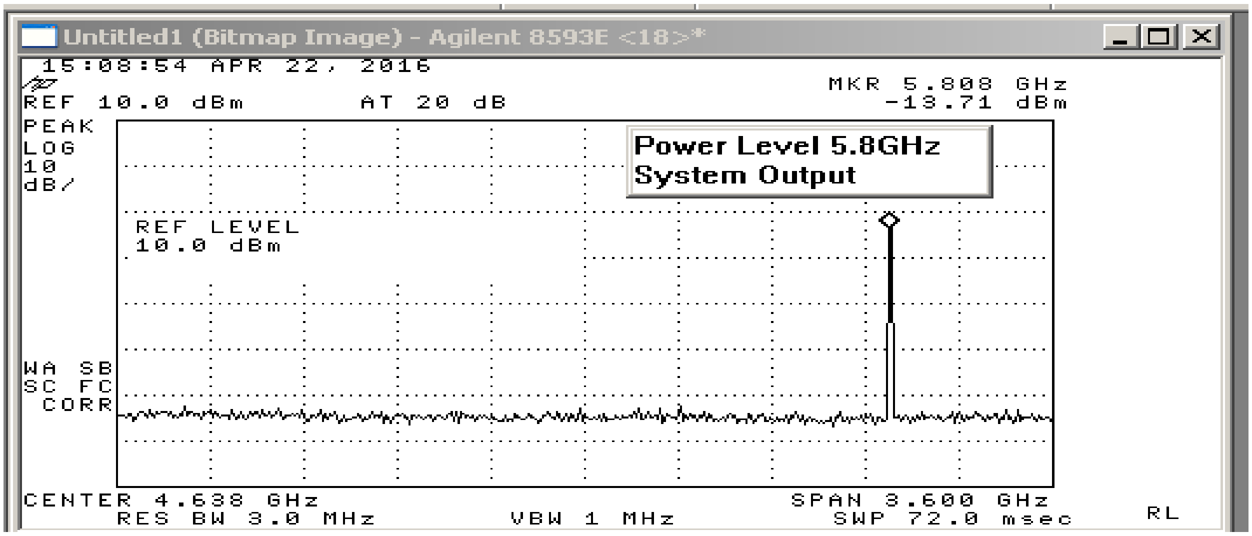


Fig. 21 Output Signal of RF to DC Converter

From Fig. 19, 20, and 21, it can be seen that the system is functioning well and is giving a proper DC output. The goal of the project was to have a DC output with less that 1% ripple. From Fig.19, it can be seen that the ripple of the system reflects that of the simulation results, which was less that .05% ripple. The following figures, Fig. 20 and 21, give a frequency domain representation of the time domain signal seen in Fig. 19. The main signal that makes it through the filtering is the fundamental frequency (5.8 GHz), which will give whatever ripple is seen at the output. This signal is dropped by 20 dB of power from input to output. This shows that the DC bypass filter designed for this project is working very well. The only other signal coming through is the second harmonic, but its power level is so low that it does not affect the signal.

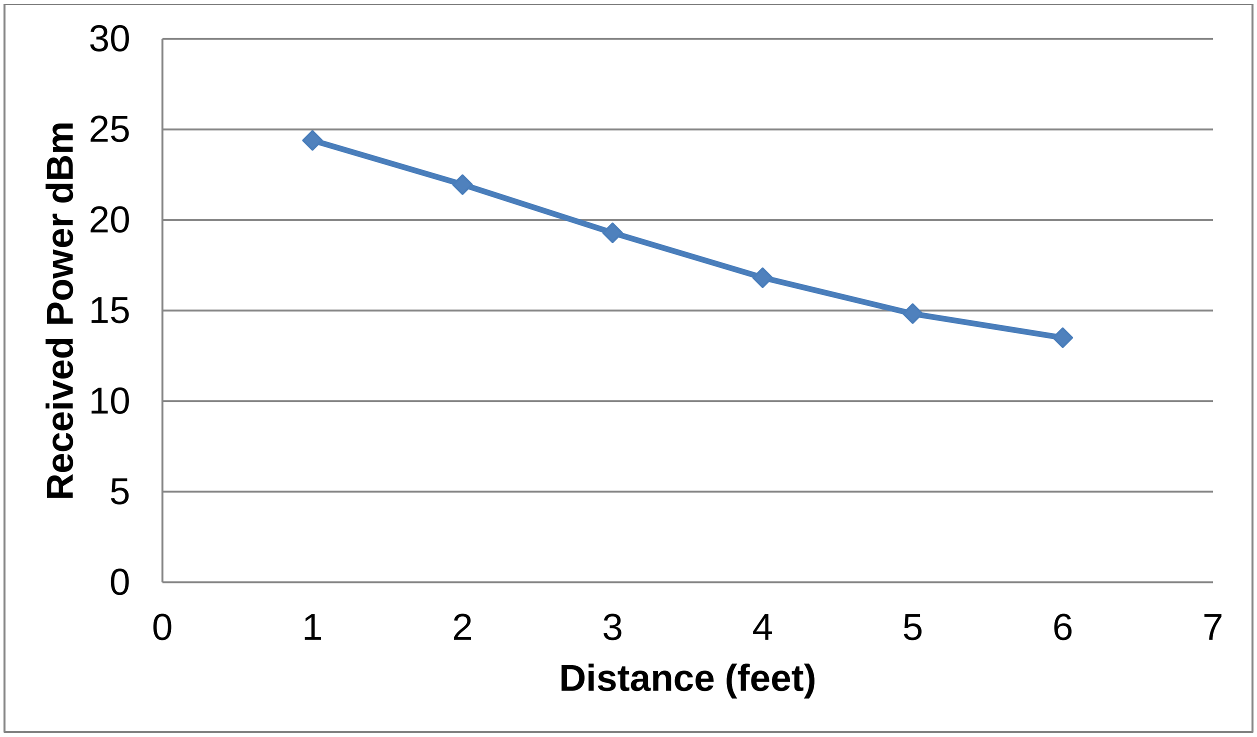


Fig. 22 Power Received at Varying Distances

The maximum power output of the amplifier for this project is 33 dBm. This power is sent to the transmitting antenna and then transmitted to the receiving antenna. Tests were run to see how much of that 33 dBm power is taken in by the receiving antenna. The main result that is focused on for this project was the 6 feet distance. This is the transmitting distance goal that was proposed at the beginning of this project. At a distance of 6 feet, the receiving antenna receives 14 dBm of power at a frequency of 5.8 GHz. This is the amount of power that would be received by the RF to DC converter if it were implemented in a wireless power transfer system, which for this project is more than enough. The received RF power vs. distance is shown in Fig. 22.

There were issues with final testing, but preliminary results show that with a 50 ohm resistance, the RF to DC converter is able to convert a 5.8 GHz signal to DC at around 40% efficiency using the unmatched network. The matched network is yet to be tested.

Chapter 7. Conclusions

The RF to DC converter project is successful on many fronts. The goals of the project are a) function at a frequency of 5.8 GHz, b) have a DC output with less that 1% ripple, c) maximize efficiency and d) minimize size.

The project does function well at a frequency of 5.8 GHz. The filtering and rectifying is able to function at this frequency and handle all of the harmonics generated. The output of the system is a very low ripple DC. Only the fundamental frequency is able to pass through the filter, but the output power level is extremely low compared to the input power, so the filtering functions well. The system efficiency is yet to be correctly determined. From research, the system efficiency goal is to be over 50%. Preliminary results show an efficiency of about 40%, so the efficiency does not quite meet the goal. The overall size of the converter is small. The converter board is 3 inch by 1 inch, which makes it very feasible to be implemented inside mobile devices.

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Appendix

HSMS-2860 Schottky Detector Diode

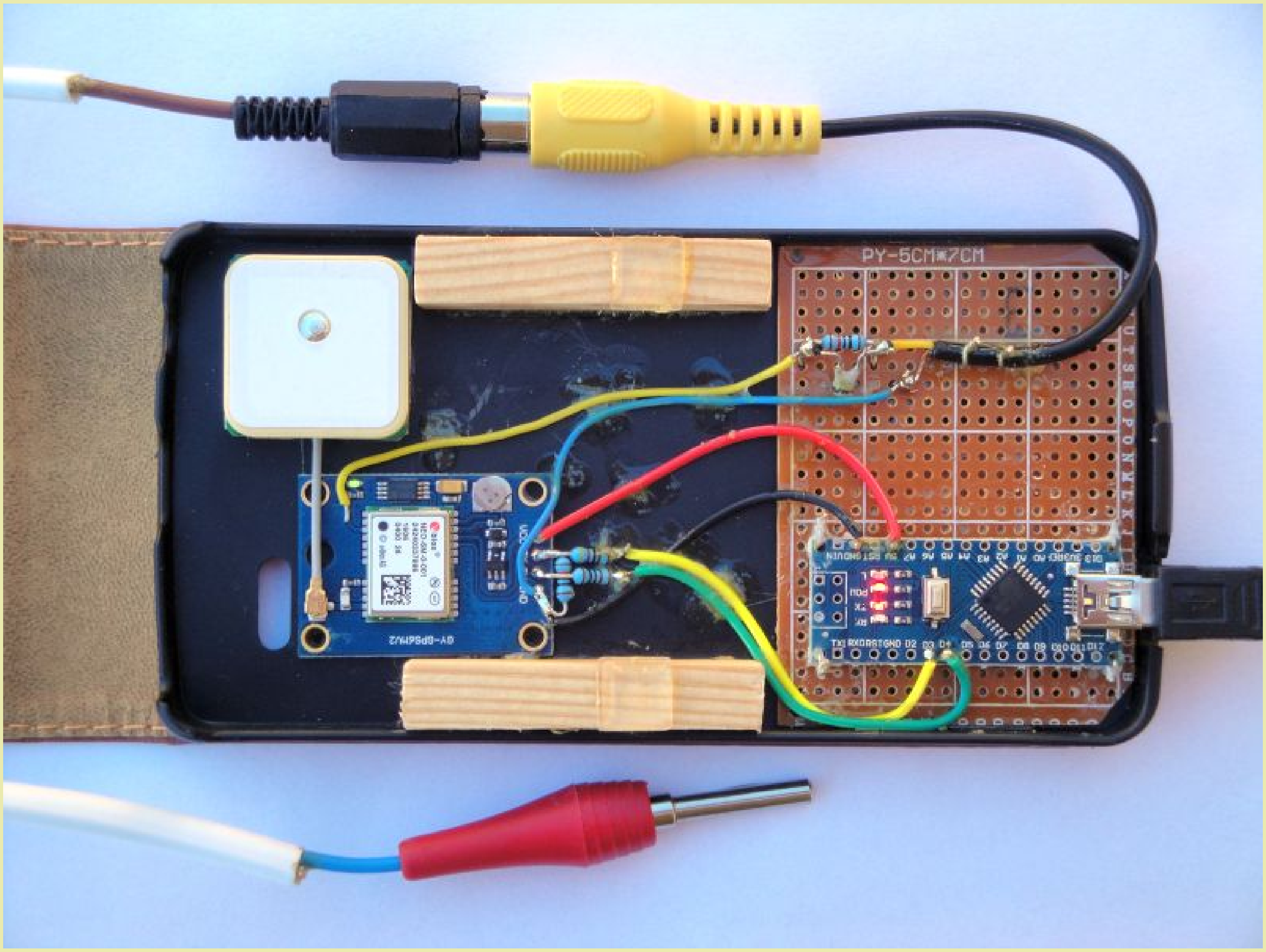
C08BL242X-5UN-X0T 2400 pF Surface Mount Capacitor

RT Duroid 5880 Circuit Board

GPS FREQUENCY STANDARD

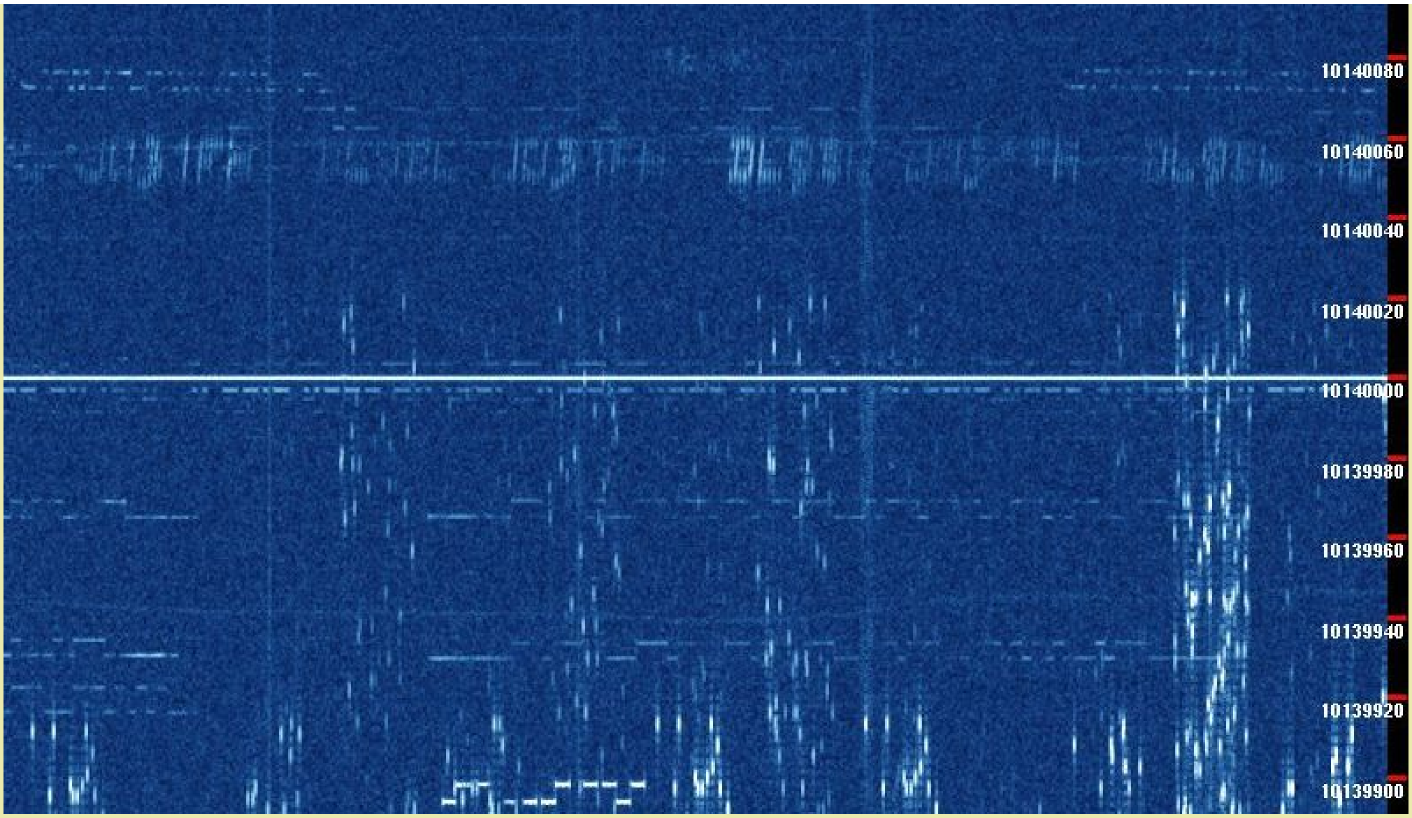
(2016)

[KLIK HIER VOOR DE NEDERLANDSE VERSIE]



The new GPS frequency standard.

GPS frequency standard
Nice toys! You can order them with one mouse click and it costs almost nothing. I bought an Arduino Nano, there were even 5 in the package for 3 euros each. And a number of other modules including a GPS module GY-GPS6MV2 of 16 euros. Could I use that for my new frequency standard? It has an accurate 1 second pulse output, a LED is connected to it. This LED flashes green when there is a fix. Many use this precise 1 second pulse to lock their frequency standard. But it can be done much easier! This timing pulse is programmable! And programmed to the maximum frequency of 1 kHz and a pulse width of 3 microseconds, it gives all harmonics in multiples of 1 kHz. Also on 10140 kHz, the frequency of my QRSS receiver. Normally we do not need such a high accuracy, but for the reception of QRSS (slowly keyed Morse signals with very low power), the receiver has to be tuned with an accuracy of better than 10 Hz, preferably more accurate!
And you can also calibrate your reference oscillator. Connect the pulse time of 1kHz to channel 1 of your oscilloscope and trigger it with this signal. Connect the signal that has to be calibrated to channel 2 and adjust the frequency so that the screen does not run to the left or right.
This GPS frequency standard comes just in time to replace my old frequency standard. It can be thrown in the trash because it is locked to the long wave transmitter Allouis that stops it transmissions at the end of this year.

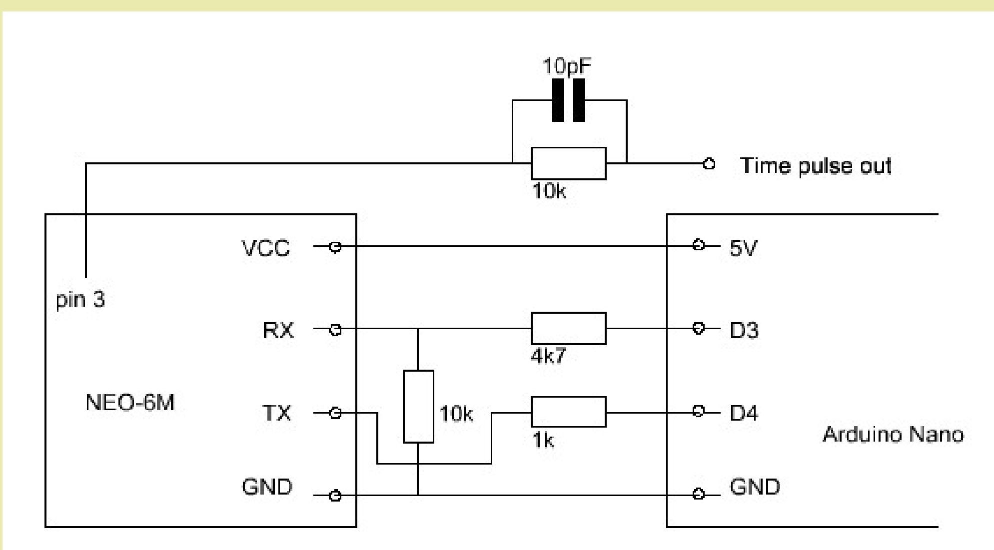


Programmedd owith a frequency of 1 kHz, the 10140e harmonic of the time pulse gives exactly on 10140 kHz an excellent usable calibration signal!

Hardware

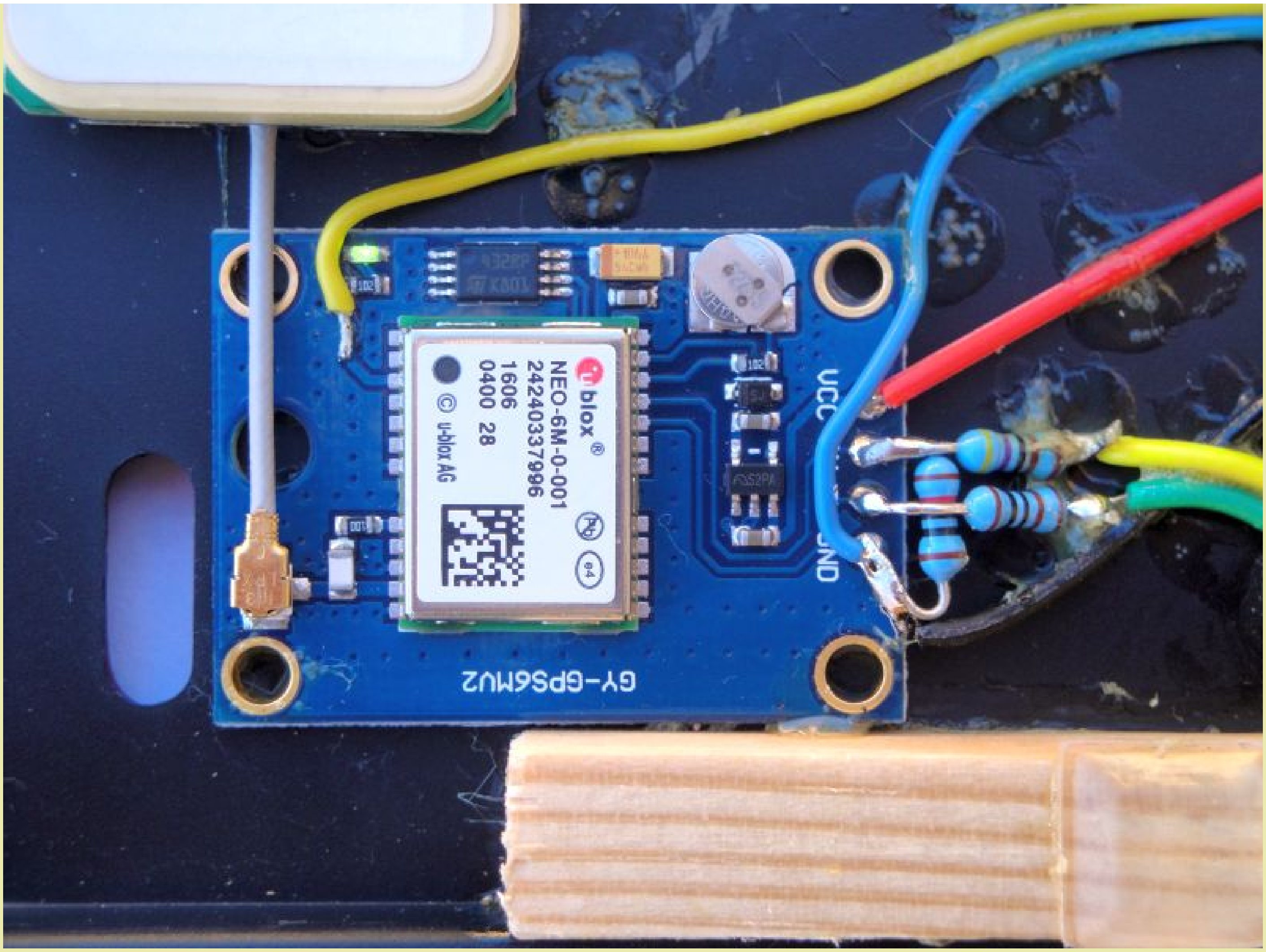
The module is built around a GPS receiver module, Model NEO-6M, type NEO-6M-0-001 of the company "u-blox AG". There is also a model NEO-6T of which the timing pulse can be programmed up to a maximum of 10 MHz. You can use it directly as a 10 MHz reference frequency source! However, this model is designed for professional applications with an external antenna on a fixed position.

Ayoma Gayan Wijethunga had described in his blog how the GPS module can be connected to the Arduino Nano and how you can communicate then with your PC with the GPS module. A very simple program in the Arduino sends the commands from the PC to the GPS module and from the GPS module to the PC. And you can see them with the in the IDE integrated Arduino Serial Monitor. And also the programming of the time pulse is very simple and will be discussed later.



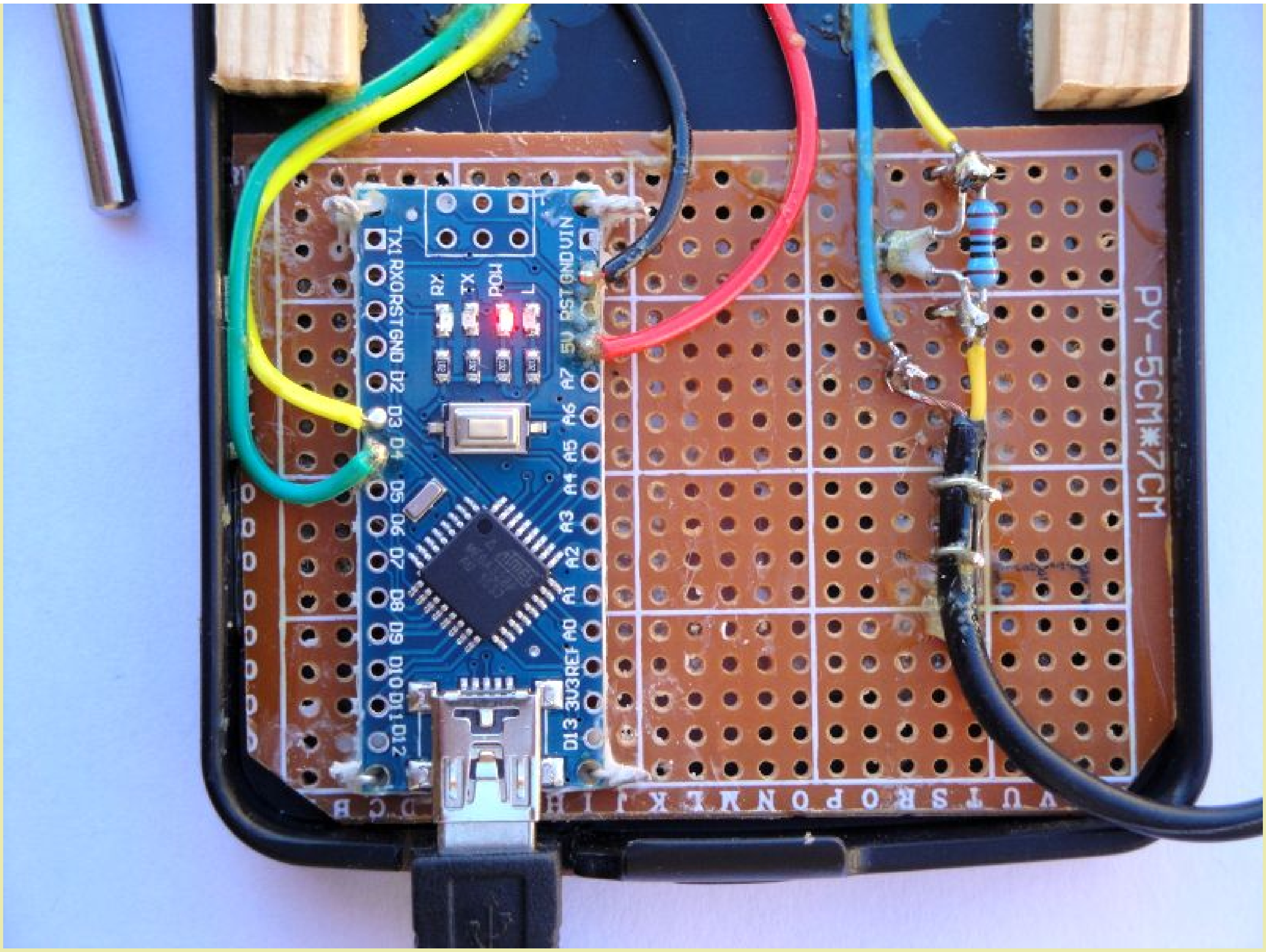
Diagram

The GPS receiver works with 3.3 volt levels and therefore there is an attenuator network with a resistor of 4,7k ohm and 10k ohms inserted between the 5 volt data output of the Arduino Nano and the RX input of the GSM module. The 3.3 volt TX output of the GSM module is just enough for the input of the Arduino Nano. I have added a 1k resistor between as security. When something goes wrong at the Arduino Nano side, it is almost sure that the GSM module will survive.



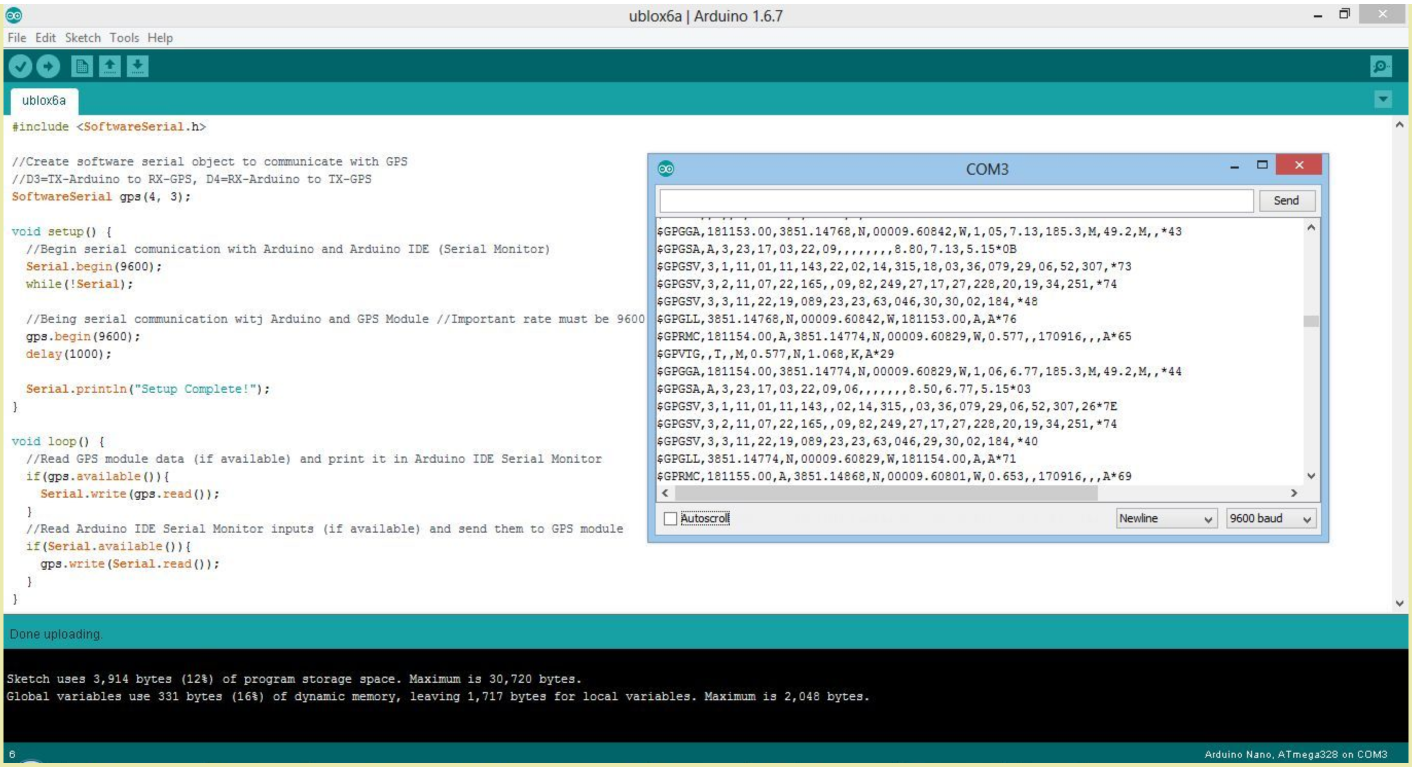
The GPS module with the connection to the time puls output

Of course, we can not connect the time pulse output (pin 3 of the GSM module) directly to the input of the receiver. Therefore, a small network of a 10k resistor and a capacitor in parallel of 10pf is made to avoid a too high load of the output.
The whole circuit is built in a hardly used phone case. The module and antenna are glued with Neophrene glue.



The Arduino Nano and at the right the coupling network between the time puls output pin 3 and output connector

The Arduino Nano is mounted on a piece of pertinax with cut-off wires and some kit. Also, the output network mounted on it between two homemade solder pins so that you can easily modify it for other applications. The solder pins also made of cut-off wires. Bend them into a U-shape, insert them through two holes and twist the ends together.



The developement environment (IDE or Integrated Developement Environment) of the Arduino.
Also the small Serial Monitor screen is visible with the data of the GPS module.

Software for Arduino Nano

Programming a micro controller has never been so easy, even a layman can learn it in a few minutes! You can find it at https://www.arduino.cc/ under downloads. And there is much more information about the various Arduino versions. I use the Arduino Nano.

Download and install the IDE. Connect the Arduino Nano with your USB port on your laptop and with "Tools - Port" you can select the correct COM port. When it works, you have the correct COM port.

With "File - Open..." you can open a program, that is a file with the extension ".ino". With the first V on the toolbar, you can check if a program has errors. With the second round with an arrow you can compile the program, uploaded it and then you are ready!

A program consists of two parts. The "void setup ()" part contains the configuration, for example which ports are configured as input or output. The second part "void loop ()" contains the program. More information can be found on the above mentioned website of Arduino.

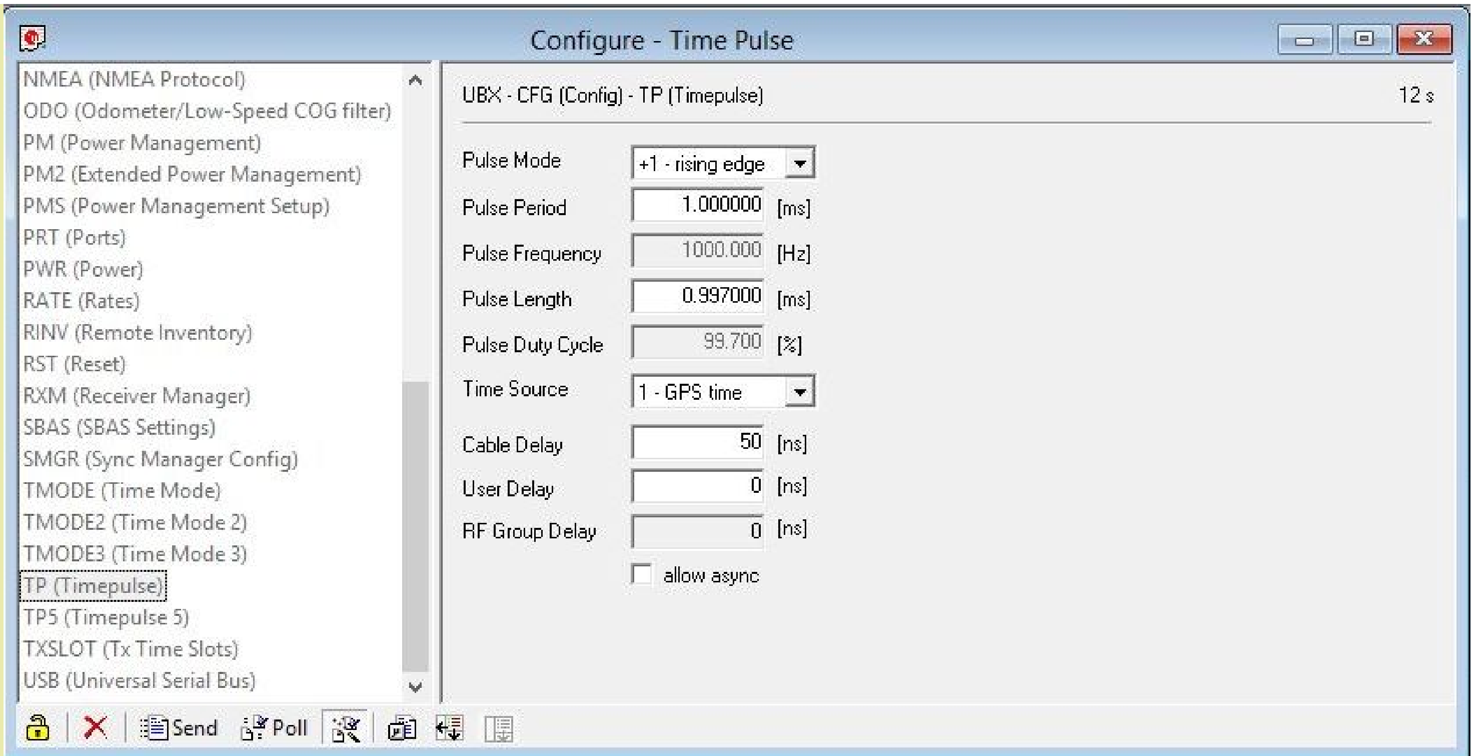
Type the following simple little program "ublox6a.ino" over and upload it by pressing the second round with arrow. Then choose "Tools - Serial Monitor" (not Serial Plotter!) And you will see the data from the GPS module appear on the monitor screen.

ublox6a

```
#include <SoftwareSerial.h>

//Create software serial object to communicate with GPS
//D3=TX-Arduino to RX-GPS, D4=RX-Arduino to TX-GPS
SoftwareSerial gps(4, 3);

void setup() {
  //Begin serial comunication with Arduino and Arduino IDE (Serial Monitor)
  Serial.begin(9600);
  while(!Serial);

  //Being serial communication witj Arduino and GPS Module //Important rate must be 9600
  gps.begin(9600);
  delay(1000);

  Serial.println("Setup Complete!");
}

void loop() {
  //Read GPS module data (if available) and print it in Arduino IDE Serial Monitor
  if(gps.available()){
    Serial.write(gps.read());
  }
  //Read Arduino IDE Serial Monitor inputs (if available) and send them to GPS module
  if(Serial.available()){
    gps.write(Serial.read());
  }
}
```

The simple program "ublox6a.ino" for the Arduino Nano.

Software for GPS module
We have already programmed the Arduino Nano and connected it to the USB port of the computer. Shut down the IDE of Arduino Nano. The Arduino Nano is now working as an USB-UART device.
We use the "u-center software" which can be downloaded from the manufacturer's website: https://www.u-blox.com/en/product/u-center-windows. With the first choice on the toolbar, you can select the correct COM port. If you do that correctly, it will work. With the program you can see lots of things like the strength of the signal of the satellites, your position on Google Maps and what we want to use, programming time pulse!



The "u-center software", the part with which we can configure the time pulse.

Select "TP (Timepulse)" to program the time pulse. As you can see, I did not program a pulse of 3 microsecond, but a pause of 3 microseconds. It does not make any difference for the frequency spectrum, but now the green LED lights up very brightly if there is a fix. With a pulse of 3 microsecond it gives hardly any light.
Do not forget to save the new setting in the "CFG (Configuration)" menu. This has to be done in the choices "BBR-0", that is the backup memory and in "3-I2C-EEPROM". Then you do not have to program the timing pulse again when you switch on the module. And now it is even possible to use the module without Arduino Nano, just connect the power and it works. But I kept the Arduino Nano for communication and future programs and developements.

The frequency standard is built in a smartphone cover. Open it to use the frequency standard.

Use

Connect the timing pulse output to your application. Maybe you should play a little with the length of the pulse pause to get the maximum signal for your used frequency.
There are many possibilities. You can program the time pulse so that you have a gating pulse of exactly 1 second for your frequency counter. Or a program a square wave of 1 kHz to lock a 10 MHz frequency standard. Or let your oscilloscope trigger on the 1 kHz signal and also connect the reference signal that has to be calibrated. If the reference signal does not move to the left or right, the frequency is set exactly.
I connect the signal to the antenna input or the earth of the receiver. For this, a special twin cord is used of 1 meter length. At one side, the blue wire is connected, at the other side the brown wire. Mass is not connected, that is not necessary. The signal is transferred via the capacitance between the two wires.
Indoors, the GPS receiver has sometimes some difficulty to find a FIX. I use a power pack as is used for smartphones when playing Pokemon Go to feed the frequency standard and then go outside. When it has found the FIX, it will continue to work well when indoors.
The used module is an outdated model, there are newer ones. See https://www.u-blox.com/en/position-time. These are also usable, and often have a time pulse output that even can be programmed to much higher frequencies.

Farewell old frequency standard that was locked onto a longwave transmitter.

[**BACK TO INDEX PA2OHH**](http://www.qsl.net/pa2ohh/)

A 0V1 TUBE RECEIVER

(2015)

KLIK HIER VOOR DE NEDERLANDSE VERSIE

A 0V1 tube receiver for the shortwave band.
Regeneration, tuning, bandselection, volume control.
Even fine tuning by moving your had towards the coil.

Old techniques: A 0V1 regenerative receiver with a tube!
When I was a beginning radio amateur, I wanted already to make a 0V1 radio receiver with a tube. But it never came so far. When I told that to my colleague Alfred, he gave me a nice present, all kinds of parts to make a 0V1 tube receiver! Because a tube receiver is totally different than one with transistors. All big parts, big resistors, high voltages, transformers, high voltage capacitors, a totally different construction than with semiconductors.

A nice present, all kinds of parts to make a 0V1 tube receiver!

What does 0V1 mean? The "0" does mean that there is no RF amplifier stage. The "V" is the detector stage. And the "1" means that there is a LF amplifier. A tube with a double triode, the ECC82 is used. The first tube is the detector with regeneration. By adjusting the regeneration correctly, the sensitivity and selectivity is increased enormously. For the reception of amplitude modulated signals, it has to be set to the point of just not oscillate. For CW and SSB it just has to oscillate.

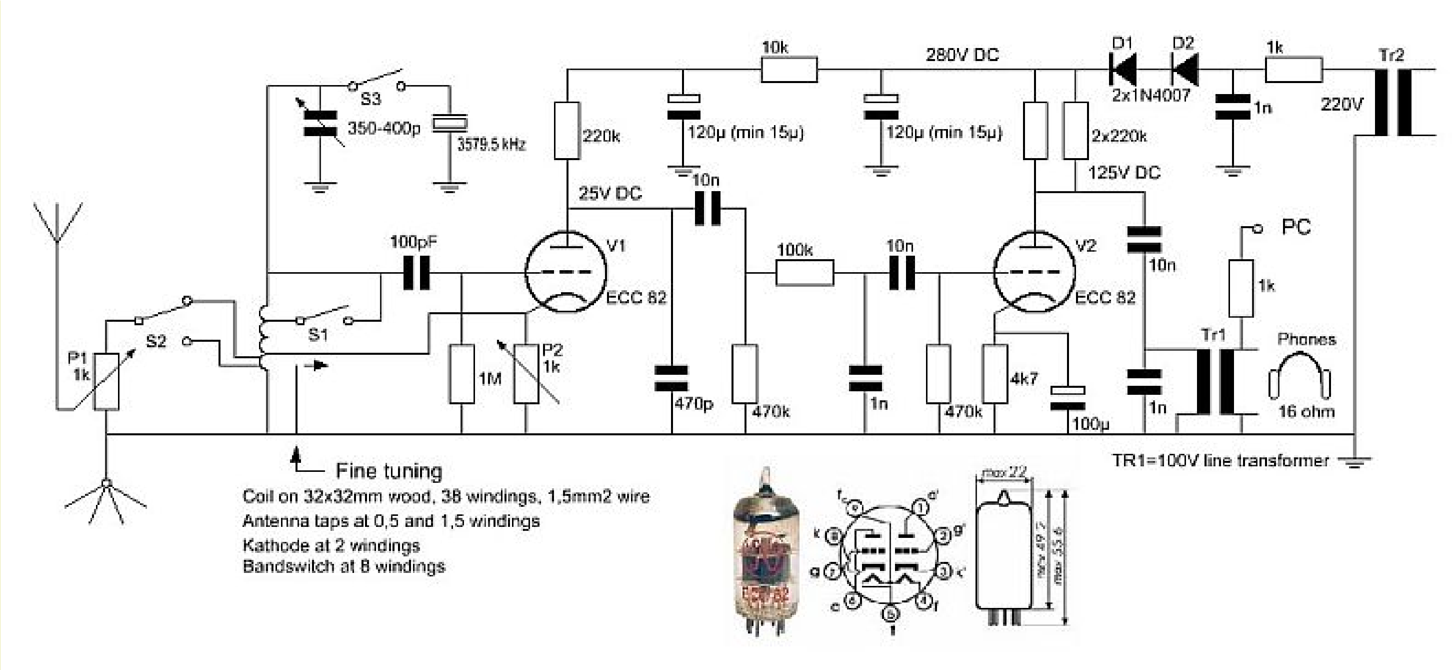


Diagram of the 0V1 tube receiver.
Fine tuning is done by moving your hand towards the coil!
[big diagram](#)

Description

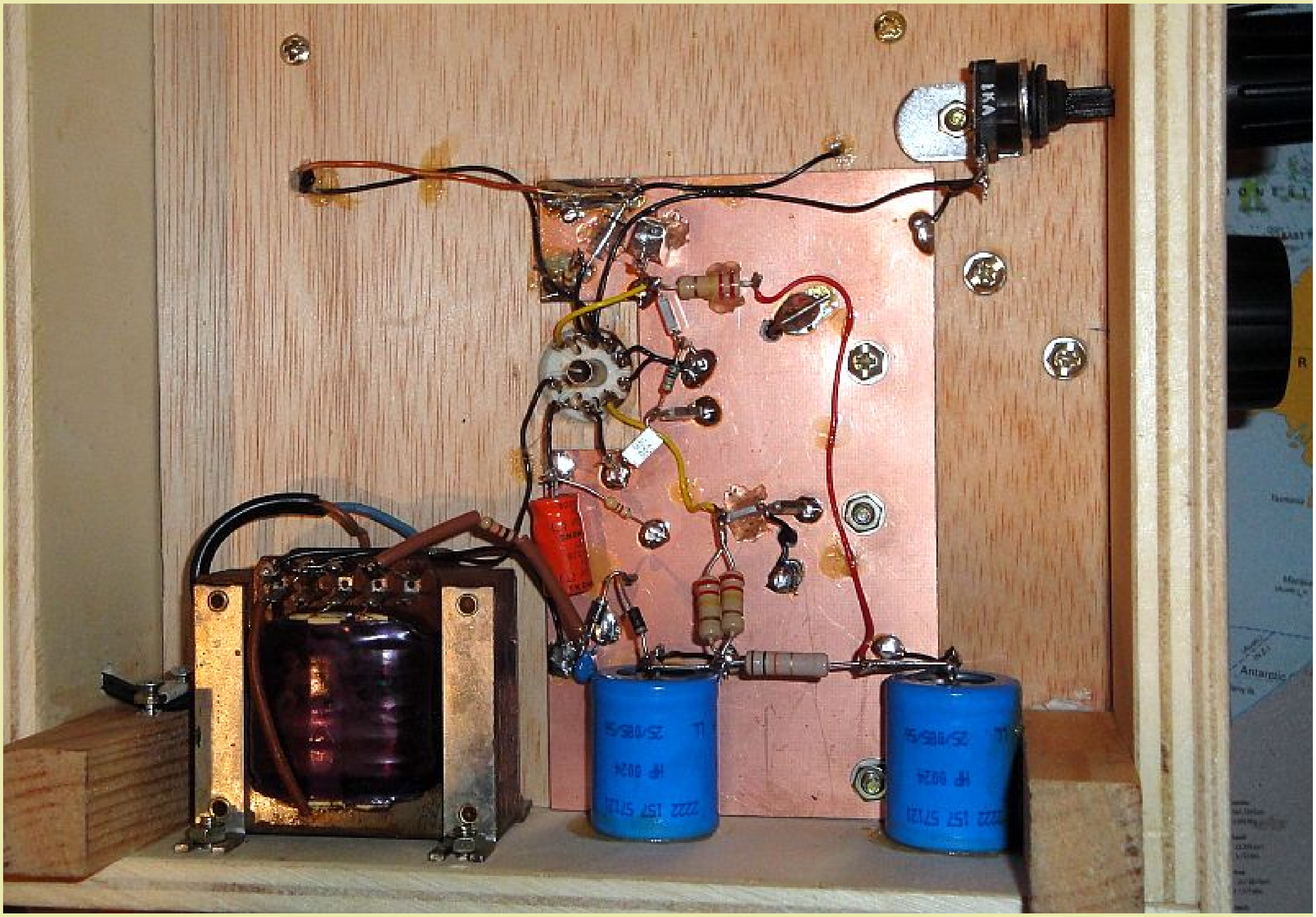
Tuning
At the input you can find the RF volume control P1 and the switch S2 with which you can select the most suitable connection at the coil, depending on the antenna and frequency band. By means of S1, a part of the coil can be shortened for the reception of higher frequencies.
And you can see a switch S3 with a crystal. Adjust the regeneration so that the receiver just oscillates. When you switch on S3, the receiver will lock to this crystal frequency when tuned close to its frequency. And then PSK31 stations around that frequency can be received.

Detector
After the coil you can find the first triode. It detects the RF signals by means of grid detection, the grid-cathode space works as a diode. For the regeneration, the cathode is connected to a tap of the coil. The feedback can be adjusted by means of potentiometer P2. When it is not possible to let the circuit oscillate over the whole frequency range, experiment with the correct tap of the cathode on the coil. Or lower the anode resistor of 220k to 100k.
The capacitor of 470pF at the anode is the decoupling of the RF signals to ground. The next capacitor of 10nF and resistor of 470k provide the separation of the DC voltage and AC signal and is also a high pass filter. The resistor of 100k and capacitor of 1nF are a low pass filter. And the next capacitor of 10nF and resistor of 470k are a second high pass filter and do have a second function. If the first capacitor of 10nF should have some leakage resistance, than this filter is an extra separation of the DC voltage and AC signal. So it is not a problem if the 10nf capacitors do have some leakage resistance.

Low frequency amplifier
Then the second triode follows, the low frequency amplifier. The cathode resistor with decoupling elco do provide the negative grid voltage. And via the 10nf capacitor, the amplified signal is connected with the LF transformer. As this capacitor does block DC, there is no high voltage on the LF transformer connections. So there are no dangerous voltages on top of the chassis!
The output transformer is a so called 100 volt line transformer that is used in audio systems in buildings. Connect your headphone to the 16 ohm connection and experiment with the best primary connection. Mine was the 0,5 watt connection.

Supply
TR2 is the transformer with a 220 volt output for the high voltage supply and 6,3 volt for the filament. This last winding is not drawn. The connections 4 and 5 are connected to ground and one side of the 6,3 volt winding, connection 9 with the other side of the winding.
The high voltage winding is connected to a resistor of 1k. The purpose is to reduce peak currents during the charging of the elco's and it is at the same time a kind of fuse. Together with the next capacitor of 1 nF, it is also a low pass filter to

suppress transients and high frequency signals. The capacitor also prevens RF hum caused by the rectifier when switching from the non-conducting to conducting state.
The rectifier consists of 2 diodes 1N4007 in series, so that there is some reserve for high peak voltages. Then you can find both elco's of 120 uF, to filter the ripple from the DC voltage. The value is quite high, the minimum value is approximately 15 uF. The supply of the detector trap has an extra filter by the second elco and the 10k resistor.



Big high voltage parts and big resistors!

Coarse tuning with the variable capacitor and fine tuning with your hand
Two shortwave ranges can be chosen by shortening a part of the coil from the top. Coarse tuning is done by means of the tuning capacitor. For the fine tuning is a very simple solution: Move your hand towards the coil!

Tube, LF transformer and coil.
Fine tuning is done by moving your hand towards the coil!

To play and experiment!
The control of such a simple receiver is totally different than working with a complicated transceiver. Especially the fine tuning by moving your hand towards the coil is a special experience, just like searching for the correct taps of the coils. It gives you a good impression about how it was in the beginning of radio. Therefore, experimenting with such a simple receiver is a nice activity, also because you should not expect that it is possible to receive so much with it. For the tuning, no scale is made and the table here below is used.

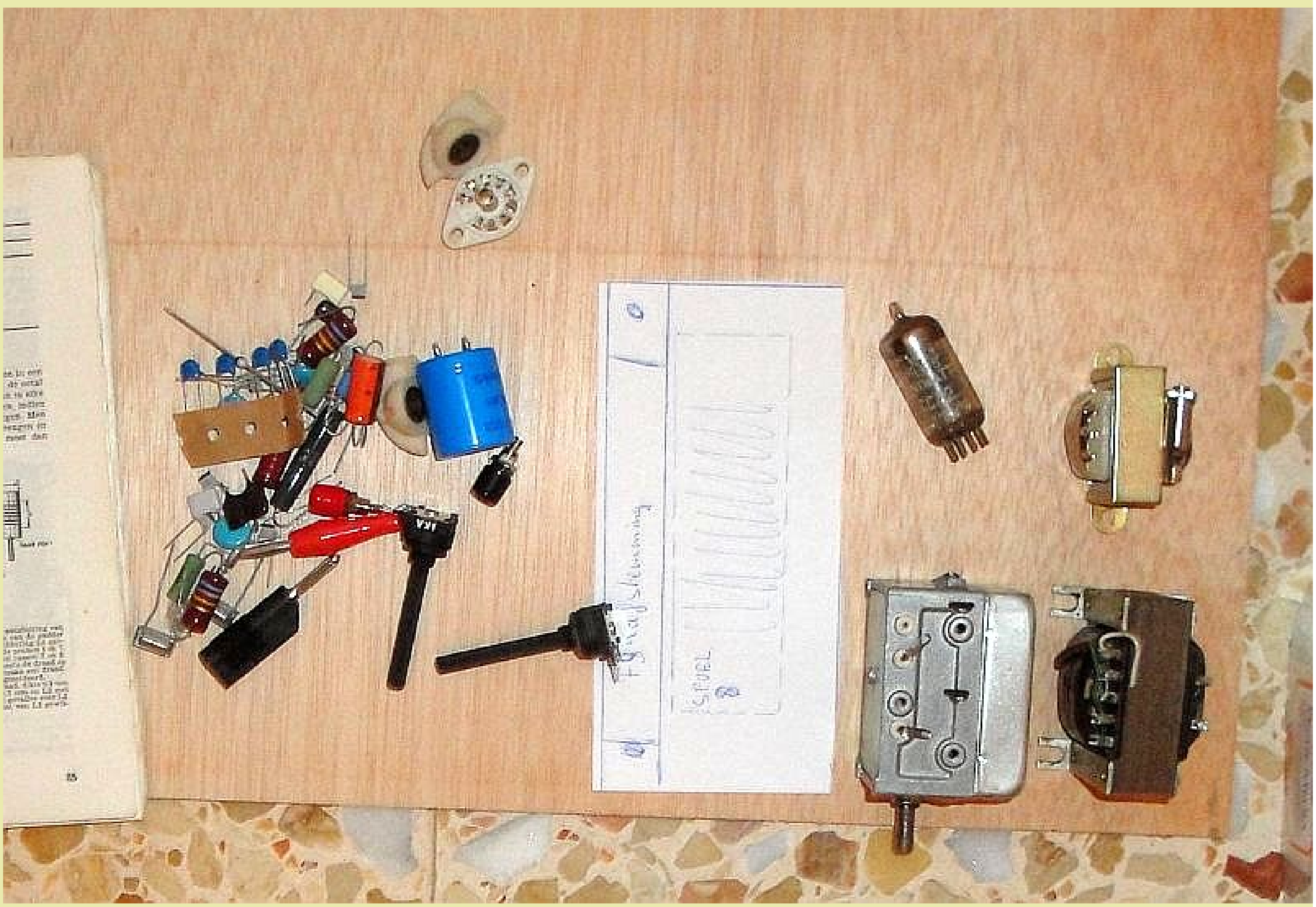
Tuning (degrees)	Band 1 (kHz)	Band 2 (kHz)
0	1700	4650
90	1950	5300
180	2400	6500
270	3100	8300
360	4000	10500
450 (360+90)	5200	13200
540 (360+180)	6450	16150
-	-	-
60	1850	-
315	3560	-

210	-	7030
350	-	10140
470 (360+110)	-	14060

Results
Unfortunately, the antenna and reception here is not so good as at my old location. But it was nice to listen again to all those shortwave broadcast stations and also CW signals could be received on various amateur bands. Here below some recordings of received signals:

CW signals
Broadcast
Broadcast

Remarks
Instead of the ECC82, also a tube ECC81 can be used, it works a little better.
A problem with the receiver is the direct coupling of the tuned circuit of the oscillating detector with the antenna. Oscillator signal is radiated via the antenna and can cause interference in the reception of other receivers. Also hum can be caused in the receiver. Many switched power supplies have rectifiers that can be considered as switches, switching on-off with the mains frequency. As the mains is connected to the antenna system via the transformer capacitor, the oscillator signal is AM modulated a little. This can cause much hum. Also the oscillating frequency can change a little in the rhythm of the mains frequency. Then the oscillator frequency is not fully stable and CW signals may sound a little rough. A solution is a 1V1, a receiver with a RF stage. The RF stage is the buffer between the oscillating detector and antenna. It suppresses the oscillator signal to the antenna and the load of the oscillator remains constant
An alternative solution is the use of an active antenna. The built-in amplifier is then the buffer between antenna and receiver.



How shall we make it? First we have to think and to make some drawings.

Under construction!

[**BACK TO INDEX PA2OHH**](http://www.qsl.net/pa2ohh/)

Implementing the X-Lock-3 on the Heathkit HW-101

Pete Juliano, N6QW radioguy90@hotmail.com

I had previously installed the X-Lock-2 in a Ten Tec Corsair I and a TR-7. Subsequently I installed an X-Lock-3 in a second TR-7. I guess you can say I am hooked! Recently I got the urge to try updating and remodeling a Heathkit HW-101 SSB/CW Transceiver. That effort entailed replacing many components and making some of the well-documented improvements. To add a modern touch I installed a digital dial from Almost All Digital Electronics (AADE). Now with the digital dial not only do I know that the radio drifts but can tell precisely "how much." That led me to install the X-Lock-3 in the HW-101. This paper documents what and how it was implemented in the HW-101. Did I mention that it was a successful install?

Just as I spent a great deal of time thinking how to install the digital dial the same applies to the X-Lock-3. The install in the Corsair I and both TR-7's was relatively easy as I simply tapped into the RIT lines and that was it. The HW-101 uses a VFO as opposed to a PTO as used in the Ten Tec and Drake radios. That meant that the VFO had to be accessed – not a hard task but one requiring some planning and thought.

This project has five distinct tasks/phases:

1. Building the X-Lock-3
2. Modifying the VFO to accept the X-Lock-3 correction voltage
3. Installing the X-Lock-3 in the HW-101
4. Building the X-Lock-3 Power Supply
5. Final Integration

Ron Taylor, G4GXO, has done a superb job in developing the X-Lock kits. The documentation is well organized and provides a step by step instruction of what to do to successfully build the kit. Since this was my third kit, the elapsed time was about an hour to build the X-Lock-3. The first build took much longer and there is much to be said for the learning curve. Once built check your wiring and for the obvious solder bridges and the wrong components in the right place. Ron has taken care to sequence and identify which parts go where and at what time. Follow the instructions!

In modifying the VFO it has to be removed from the radio! To gain access to the VFO circuits here is the sequence to follow:

- Start by removing the main tuning knob and panel mounted vernier drive. Two screws attach the vernier drive to the front panel and there are two set screws on the vernier that fasten the external panel mounted vernier to the internal vernier inside the VFO enclosure. There are four screws that are seen once you remove the knob. Two fasten the vernier to the front panel and two fasten the vernier to an adapter plate. You want the two that hold the adapter plate to the front panel. Finally loosen the two

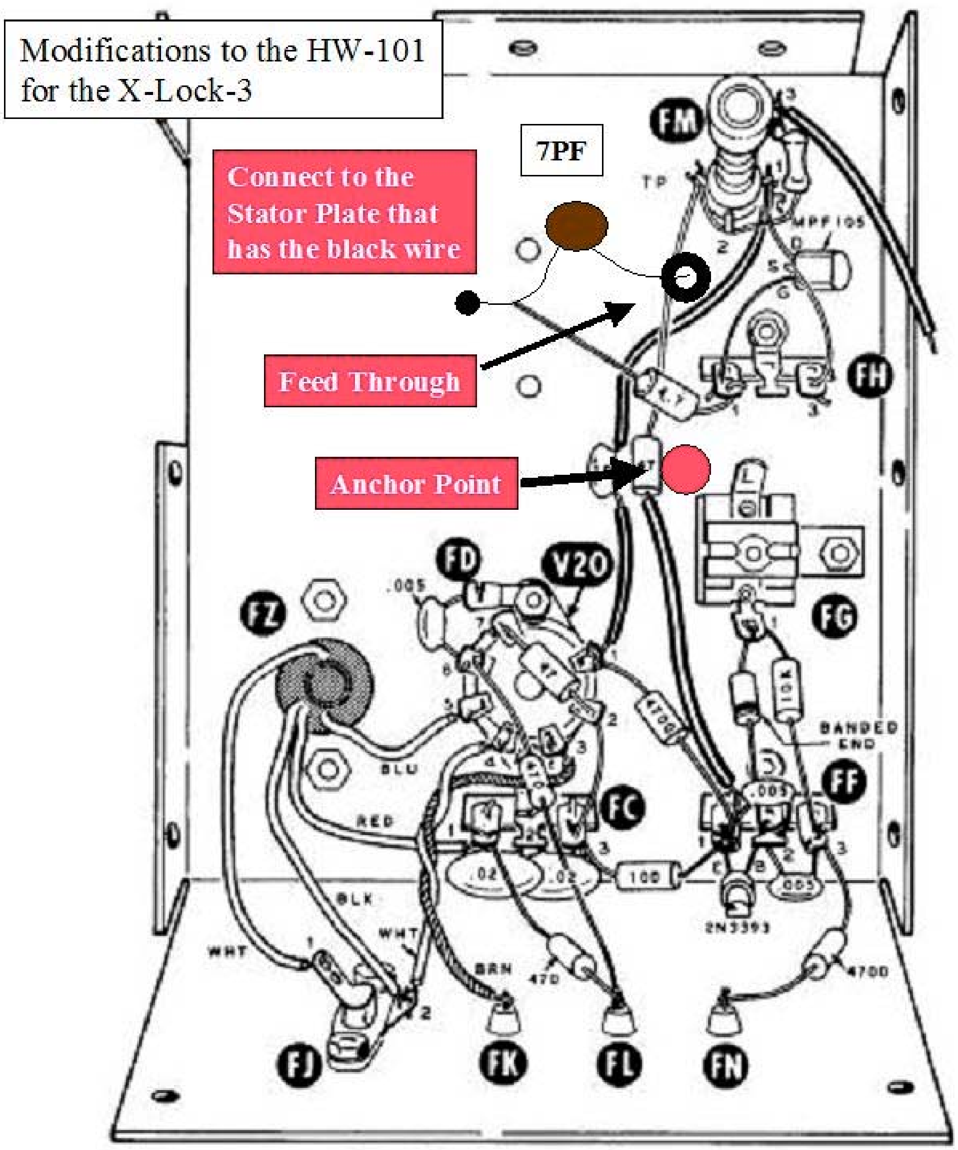
setscrews and remove the vernier. Set that in a safe place along with the panel mounting screws.

- Unsolder the three wires at the back of the VFO enclosure and unplug the VFO output cable. With a pencil I marked on the top of the VFO enclosure the wire colors that went to the feed through devices, W for the Bias, O for the B Plus and B for the Filament. [The wire colors were white, orange and brown.]
- Disconnect the SSB filter (and CW filter if installed). Remove the filter (s) from the L Bracket. Remove the L bracket by unloosening the two nuts. You will hear the two holding screws drop into the VFO enclosure. [Upon re-assembly I taped the screw heads to the chassis using masking tape. This will hold the screws in place until you can put the lock washers and nuts back on.] The reason the filter L Bracket must be removed is to provide access to two of the four bolts holding the VFO assembly on to the main chassis. Put the L Bracket and hardware in a safe place. Next remove the four nuts holding the VFO enclosure to the chassis and put the 4 lock washers and nuts in a safe place. [Long ago I purchased a multi compartment plastic box, which I use to collect the parts and hardware. It has been a lifesaver. This has greatly reduced lost parts and lost hardware.]
- Gently pull up and back on the VFO enclosure until it is free of the chassis. The underside of the VFO enclosure is open and provides ample room to make the necessary modification to the VFO. The VFO box could be further disassembled but I was unable to loosen the two setscrews that hold the internal vernier to the tuning capacitor. But in retrospect that was probably a good thing and in the final analysis not required.
- The first modification is to remove the fiber standoff that was originally a part of the dial correction “zero set” mechanism. The removal is necessary to provide clearance for the tri-color LED that will fit in the front panel hole. This LED is needed to observe the “LOCK” state.

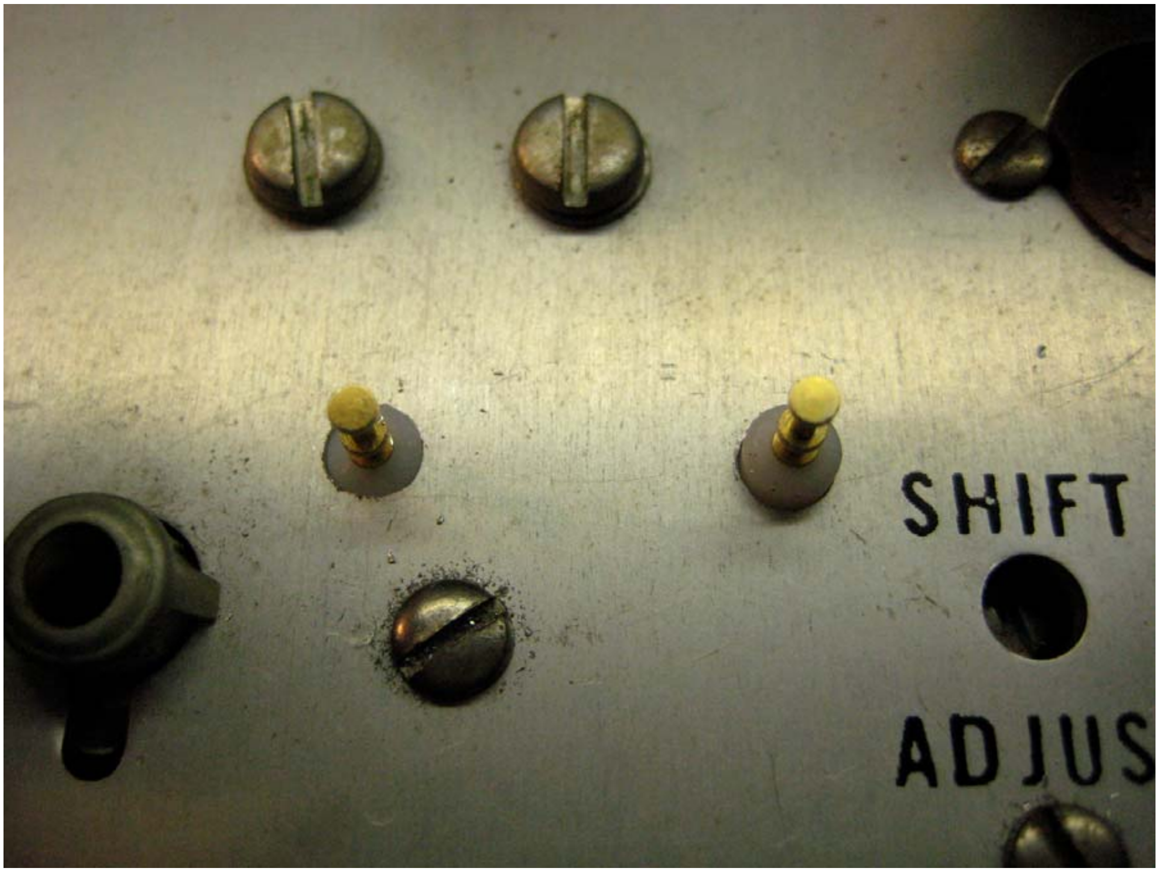
In the X-Lock-3 installation instructions several key points were made and this is where paying attention is important. Since a connection to the VFO tank circuit must be made, the caution here is to keep leads short and direct. Another caution is that there must be some “diddling” of the tank coupling capacitor to assure optimum operation. In practice you want the VFO to change frequency about 20 kHz as a voltage from 0 to 12 VDC is applied to the 1N4004 Diode. Two capacitors were supplied with the kit, a 22 PF and a 68 PF. As is mentioned in the instructions a smaller value of capacitance may be required depending on the individual tank circuit components. I found that it only required 7 PF for the 20 kHz shift based on where I connected the X-Lock-3 to the tank circuit. An adjustment to coil L941 must be made to reset the tuning range once the new cap is installed. So the questions are where to connect to the tank circuit and how do you do that so that frequency stability is not impacted. Refer to the two diagrams out of the Heathkit HW-101 manual to see where to put the holes and the second shows the connection point in the VFO circuit.

Following are a series of photos that detail the actual modifications. In the first one I show where to locate the two holes as seen from the underside. The second shows the actual location of the two small holes fitted with the feed through and the anchor point.

The third photo shows how the interface electronics following the X-Lock-3 are installed on the top of the enclosure. The fourth photo shows the schematic of where to install the 7 PF Silver Mica coupling capacitor. The fifth shows the install in the VFO.



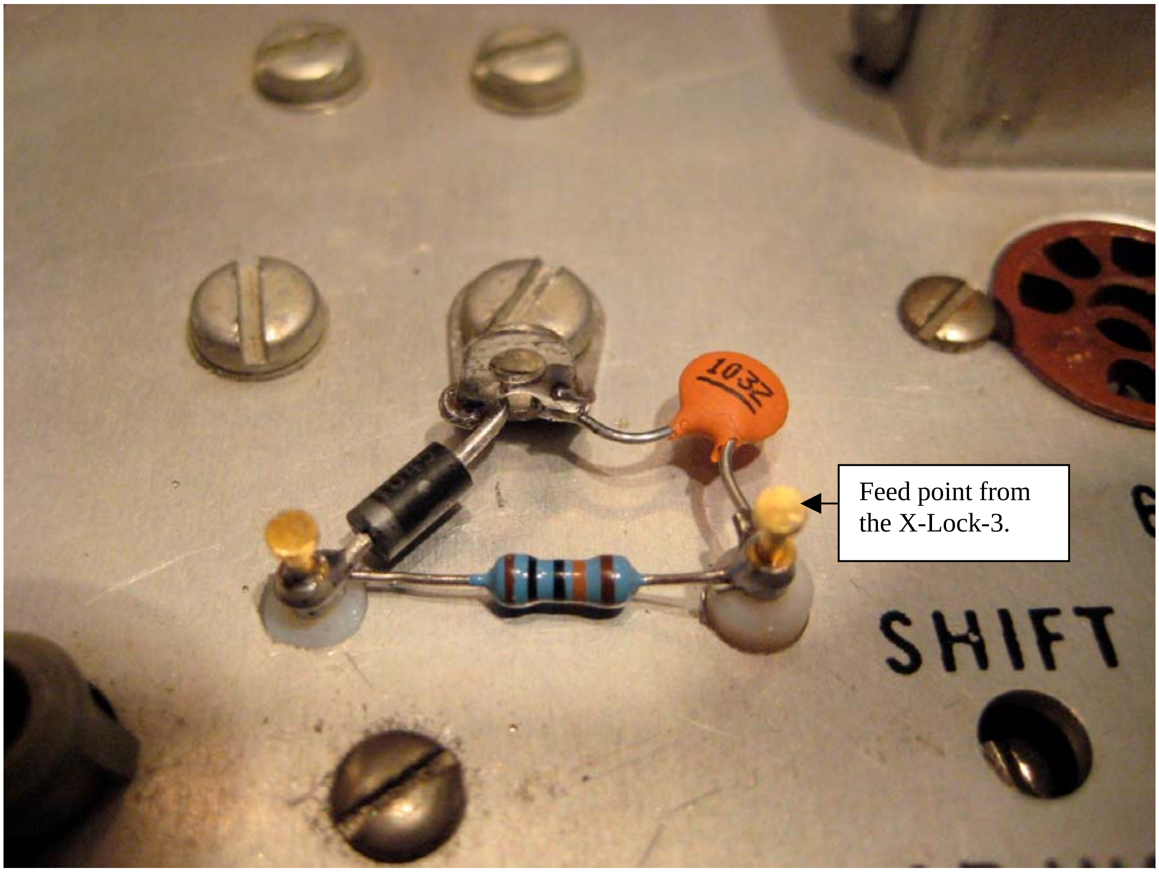
Two pass through devices are installed in the HW-101 VFO Case. One is modified to act as a "feed through" type and the other is an anchor point that is used to make connections on the top side of the case. The 100K resistor is connected to these two points on the outside of the VFO. The 7PF cap is connected from the Feed Through to the Tank.

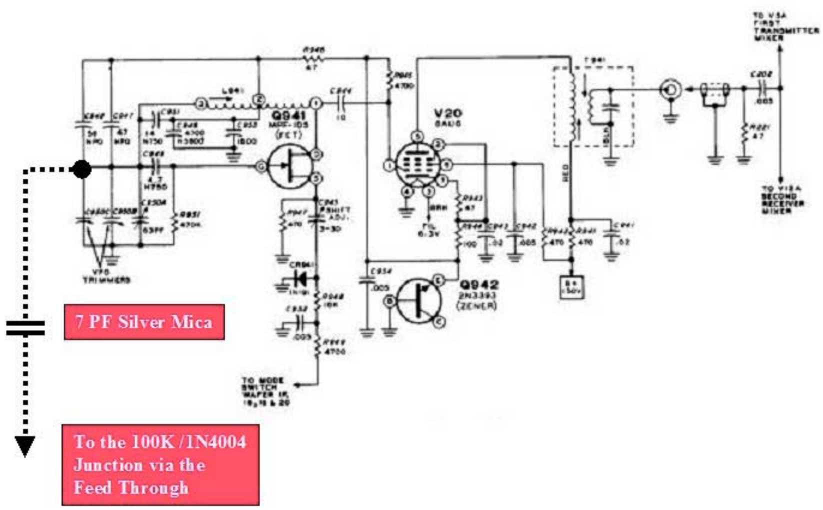


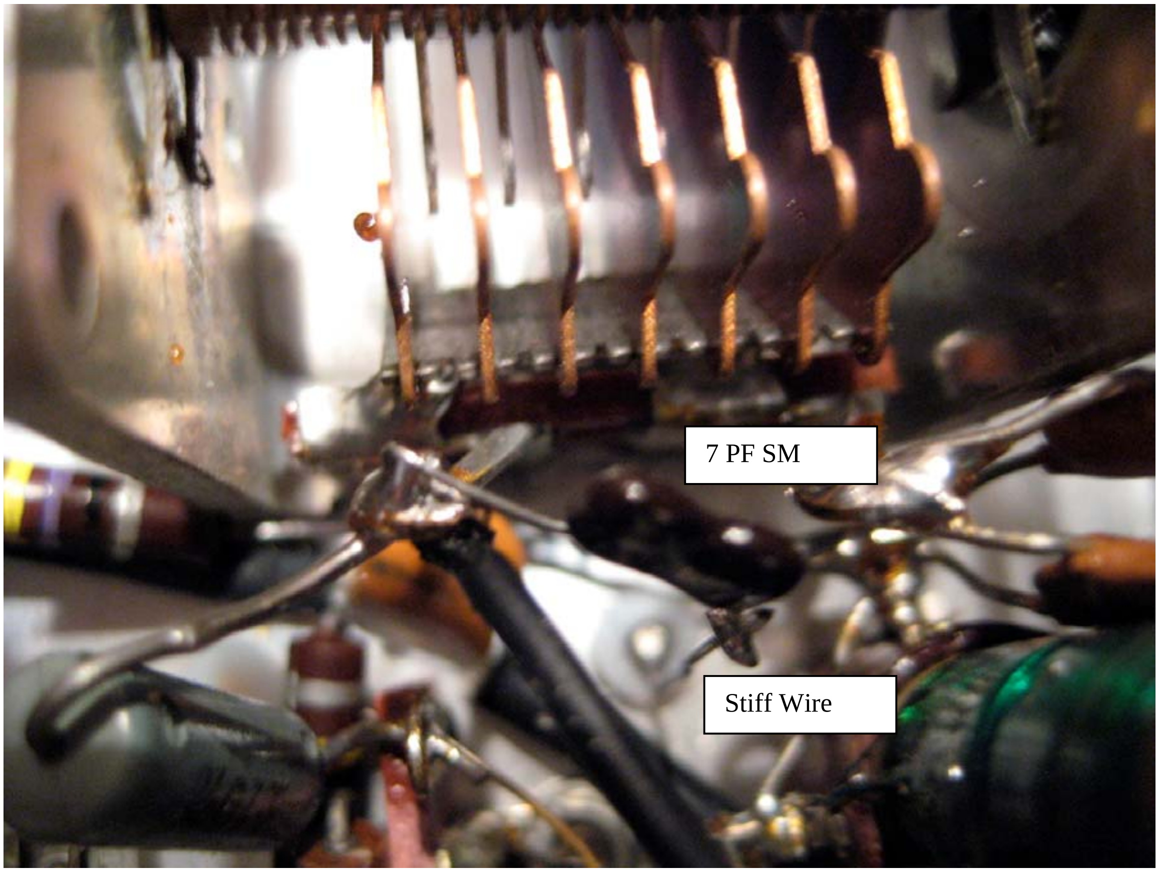
Note that the feed through was made from a second standoff. I simply cut the insulating teflon about 1/16 inch from around the barrel and then cut a hole in the bottom of the teflon barrel. I was able to push the gold pin through the hole and there is a stop on the shaft to stop the shortened teflon barrel. Thus I had a connection points at either end. You can observe the shortened barrel and length of the gold post in the left feed through. On the underside of the feed through I soldered a very stiff wire as an anchor point since I would be testing various coupling caps and this enabled making component changes.

A note about the feed through and the anchor point in terms of installation. When drilling the holes in the top of the chassis use a drill smaller than the Teflon barrel diameter. Then with a small fine round file carefully enlarge the hole while constantly testing if the teflon will fit into the enlarge hole. Stop just at the point where it almost fits and then “press fit” the feed through and anchor point so it is a tight fit. This will anchor them so there is no movement. This takes time to do –so don’t rush it!

A solder lug was fitted to one of the screws which anchor the variable capacitor and this provided a convenient connection point for grounding the anode end of the 1N4004 and the 10 NF bypass cap. This arrangement provides for short component connection leads. This is a very stout install so there is no physical movement of the components. [Keep in mind where prior planning makes the job easier.]


1032
Feed point from the X-Lock-3.
SHIFT


Q941
V20
Q942
7 PF Silver Mica
To the 100K /1N4004 Junction via the Feed Through

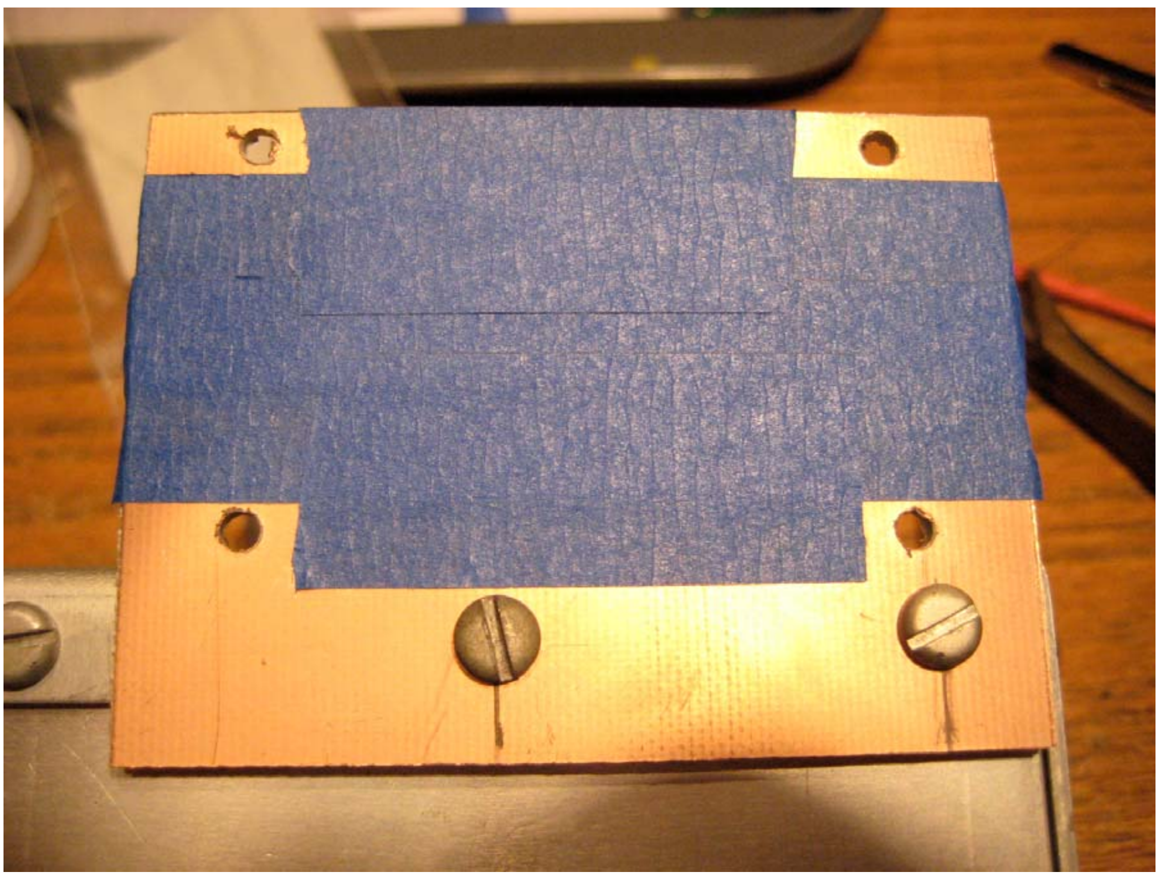


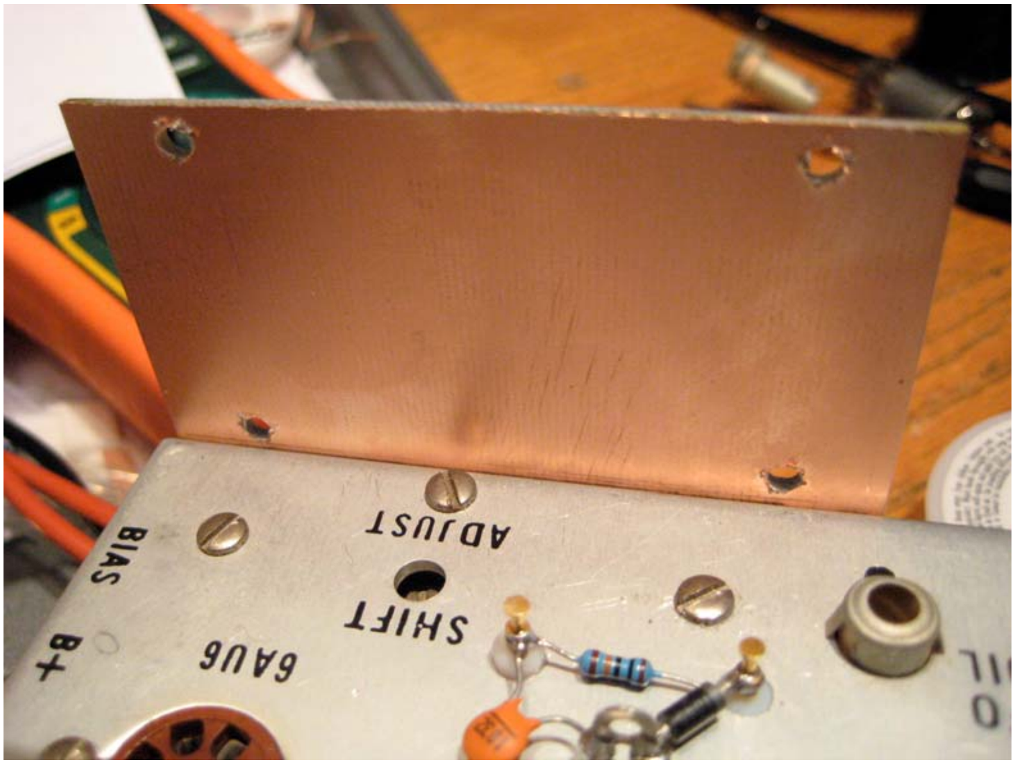
At this point it would be a good idea to test the VFO with the modifications BEFORE re-installing the unit back into the radio. This can be done in several ways. I happen to have a power supply that will supply 6.3 VAC and +108 VDC Regulated. I temporarily hooked up this supply to the VFO. To the 100K resistor at the supply end I applied a variable DC voltage of 0 to +12 VDC. Using a frequency counter connected to the output I was able to determine the optimal value of the coupling capacitor. Initially I started with the supplied 22 PF and running the DC voltage through its range found the Delta frequency change to be on the order of about 60 kHz – way too large. I then tried a 4.7 PF NPO capacitor and the Delta frequency change was only about 14 kHz –too small. So then I tried the 7 PF Silver Mica and that was almost exactly 20 kHz –which is what G4GXO suggested as optimal.

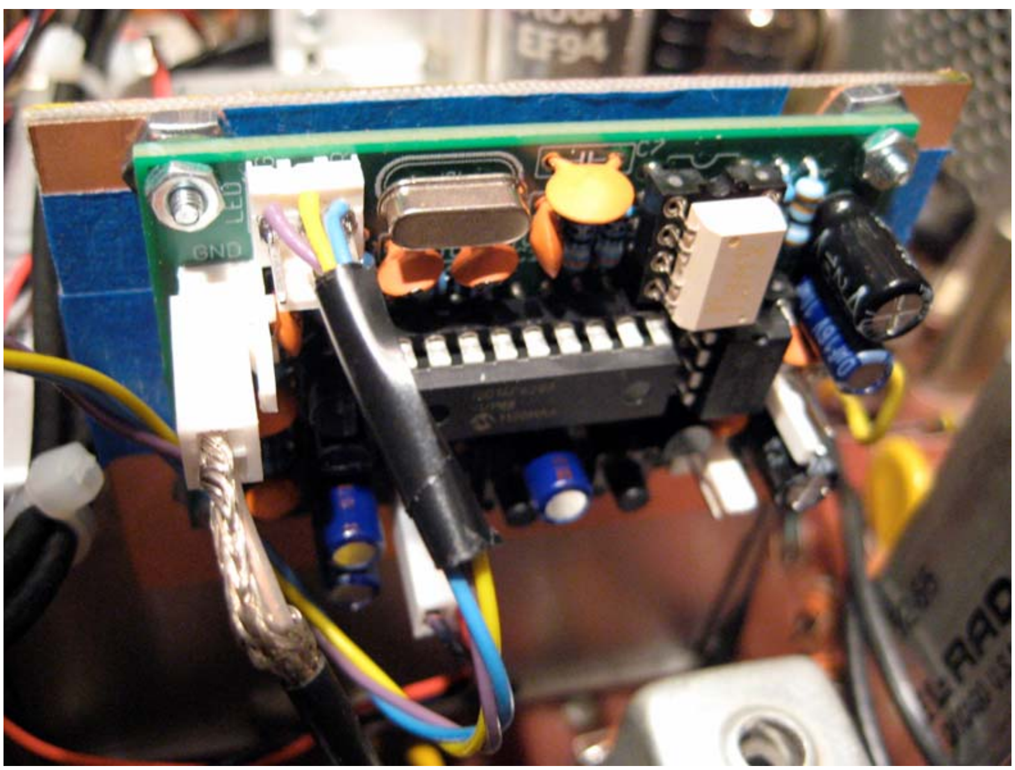
So what do you do if you do not have the digital dial installed and do not own a frequency counter and don't have a special power supply? Improvise! You can make a short power cable of about two feet of wire and hook up the power cable to the HW-101 connection points and then connect to the VFO. Be sure to include a ground wire as the VFO gets its ground return through the metal to metal connection. In my case I have the digital dial installed and could have read the frequency by connecting a jumper cable from the VFO output port to the input on the HW-101 VFO input port. This gives a whole new meaning to "remote VFO". But if you lack some sort of digital display or counter you can listen to the output on a general coverage receiver tuned to 5 MHz and listen for the VFO output. I did that too in addition to having the frequency counter on the

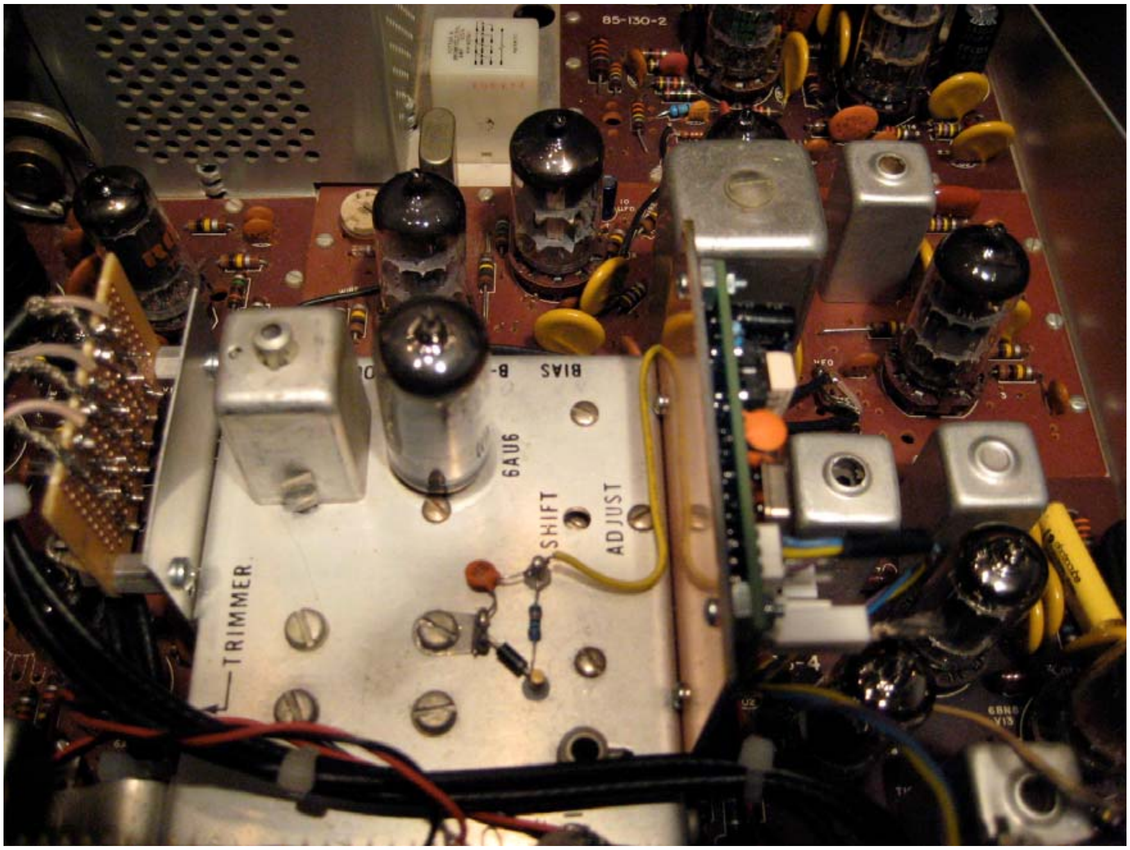
output. Once you are assured that the VFO is working and the frequency spread is as it should be disconnect the wiring and re-install the VFO in the reverse sequence. Start first by taping down the two screws that hold the L shaped crystal filter bracket. Next install the VFO enclosure etc.

Now where to install the X-Lock-3 in the HW-101. As luck would have it there is a perfect place right on the VFO enclosure. This will keep the leads short while providing access to the X-Lock-3 for any on-board adjustments. The “magic answer” to install the X-Lock-3 is a piece of scrap double-sided copper PC Board. Along the left edge of the VFO enclosure are two large sheet metal screws that connect the two sections of the VFO enclosure. These provide anchor points to vertically mount the PC Board while at the same time the PC Board serves as a base plate to mount the X-Lock-3. There is nothing critical about the size of the PC Board other than it be large enough to hold the X-Lock-3 and provide a mounting lip to mount to the VFO enclosure. I used four large 6-32 nuts as spacers to elevate the X-Lock-3 from the mounting board. To assure no shorts I covered the PC Board with a layer of 3M masking tape. See below.




ADJUST
SHIFT
BIAS
B+
6AU6

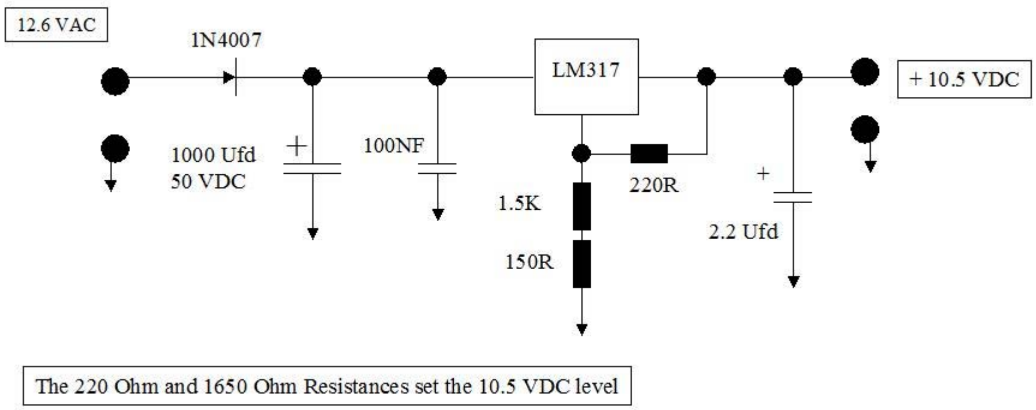

EF94
LED
GND



The above is a plan view of the X-Lock-3 installed along the right hand edge of the VFO enclosure and the yellow wire carries the correction voltage to the 1N4004. The circuit board along the left-hand edge is part of the signal level adjustment for the digital dial. The tri-color status LED has the normal 3-pin connector installed so it can plug onto the X-Lock-3. But I also installed an eight-inch long 3-wire cable to the X-Lock-3 board LED connector and put a mating plug on the end of the cable. This enables remote viewing of the status LED. I bent the LED at a right angle so it would fit in a panel mounted LED socket than now occupies the space where the Zero Set Control was located. I used some electrical tape around the exposed LED wires to prevent any shorts to the chassis. See below.

The next phase is to build the DC Power Supply to power the X-Lock-3. G4GXO recommends a supply voltage in the range of +10 VDC to no more than +16 VDC. The reason for the + 10 VDC is that the X-Lock-3 has two on board regulators, one at + 5 VDC and the other at + 8 VDC. You need a several volt differential to have the + 8 VDC regulator to work properly thus the + 10 VDC. On the other end you need a several volt differential to produce + 10 VDC. The source that was chosen was the 12.6 VAC filament supply that was run into a 1N4007 diode that is configured as a simple diode rectifier. Given the low current draw you would expect around 13 or so VDC coming from that rectifier which is more than ample to drive an LM317 Adjustable voltage regulator. By selecting two values of resistors it is possible to develop a whole array of fixed output, regulated voltages. There are calculators and look up tables on the Internet that give the values and expected outputs. I chose 220 Ohms and 1650 Ohms. With these values the LM317 outputs +10.5 VDC –perfect! Below is the schematic of the power supply to power the X-Lock-3. The LM317 has another function in that it will “clean up” the input signal, so that is a bonus. The power supply was built on a small piece of Radio Shack Perforated Board and mounted on the underside of the chassis.

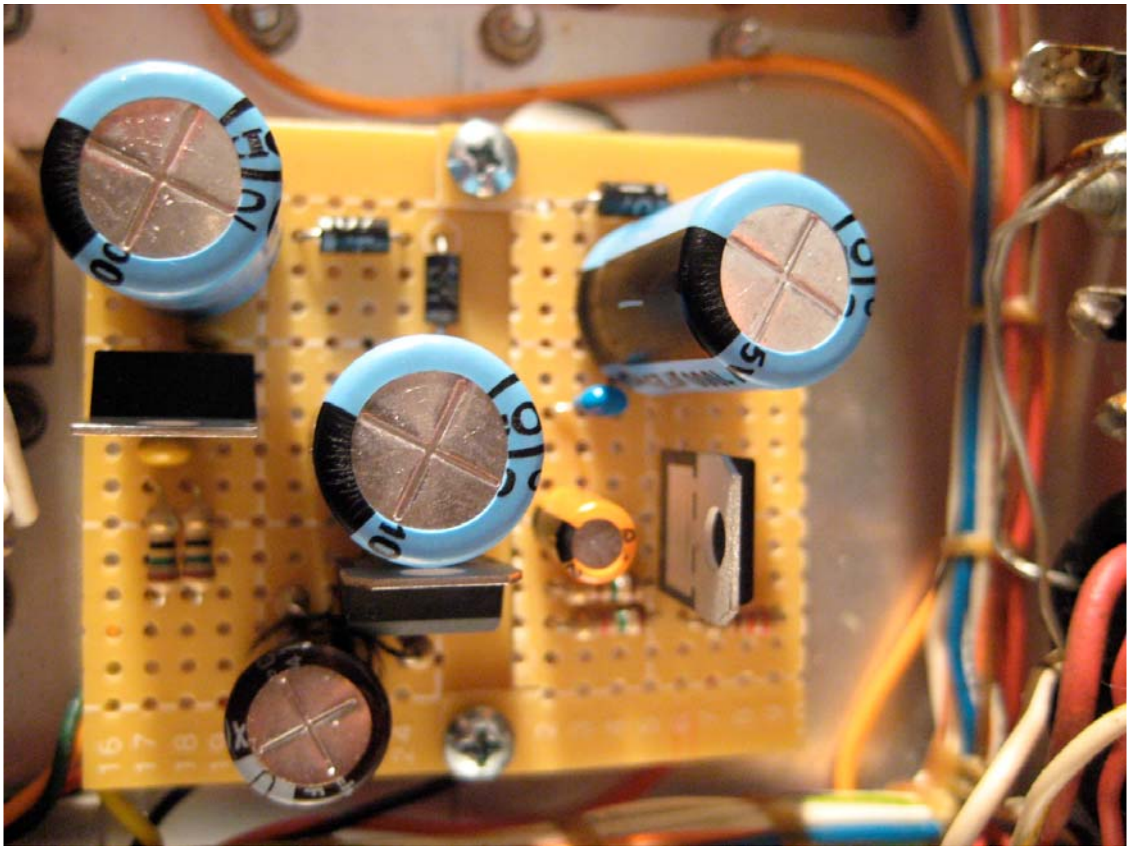
X-Lock-3 Power Supply



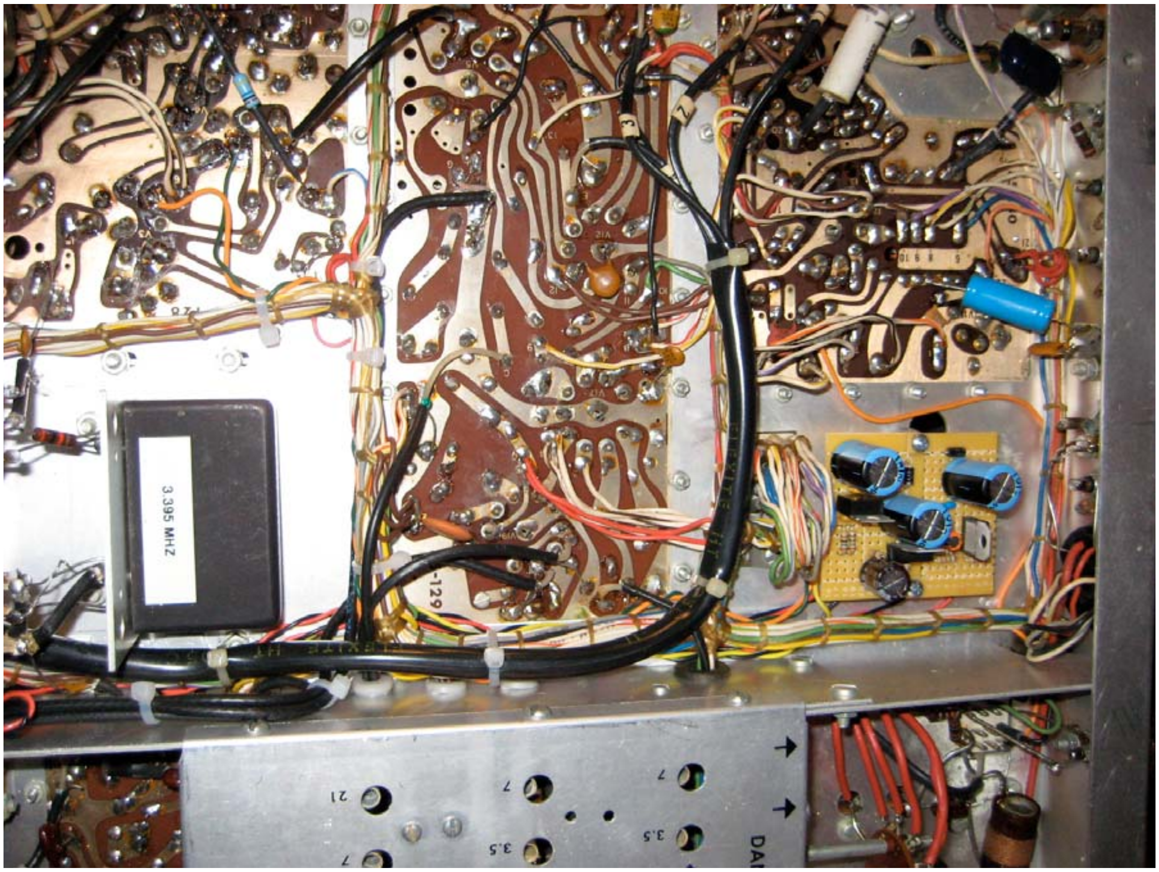
Note the HW-101 is primarily a vacuum tube radio and therefore there must be a low level power source to power the X-Lock-3. The 12.6 VAC Filament Supply is used to provide the final source voltage of 10.5 VDC to power the X-Lock-3.

N6QW 2012

In the Drake vacuum tube radios of the same vintage, that frequently had solid state as well as vacuum circuitry, the Drake engineers simply used dropping resistors off of the low voltage screen/plate supply. Needless to say there was a lot of heat just to get +12 VDC.



These are the two power supply boards, one for the digital dial and the other for theX-Lock-3. The one of the right is the X-Lock-3. It was difficult to find space on the underside of the HW-101 to add circuit boards. I found one spot where I could install two aluminum pillars approximately 3/8 inch high that were spaced the exact width of the Radio Shack Perforated Board. One of the pillars mounting holes was actually inside the PA cage. So as you can well understand – measure 40 times and cut once. In order to utilize a single set of pillars to support both power supply boards, I notched the power supply board for the X-Lock-3 so that the board mounting holes could be utilized and yet the board itself not interfere with already installed components. If you look carefully at the top mounting screw you will see three diodes, which are all 1N4007. These three diodes are fed with 12.6 VAC from the filament rail to develop three separate DC voltages. The point is that I was able to make relatively short connections from the 12.6 VAC rail to the three supplies that are on the two boards. Measure 40 times and cut once. It was no accident that the boards were laid out this way! The three supplies develop 9.66 VDC and 5 VDC for the Digital Dial plus 10.5 VDC for the X-Lock-3. For those skilled at making printed circuit boards this of course would make the install much easier as a smaller footprint board could be developed. Below is a birds eye view of the bottom side of the HW-101 to give you a feel of the not too much available space to add circuit boards.



The last phase is the final integration and that is to simply connect the VFO input that was sampled from the lead going to HW101 circuit board. The power was connected to the X-Lock-3 and a lead was connected from the voltage correction pin to the correction circuit installed on the top of the VFO enclosure. At power on the status led goes through its start up sequence only it will blink “red” for several seconds – the buffer stage following the solid state oscillator is a vacuum tube and will have no output until it is warmed up. Then it will lock “green” indicating that it is working. Now the digital dial reading does not move!

One very nice feature of the X-Lock-3 is that operating CW. It is so cool to key the radio and see the digital dial display change to the CW offset frequency and then return to the stored frequency when you have completed the CW keying sequence. Thank you Ron for including this feature in the X-Lock-3!

With the Digital Dial and the X-Lock-3 this is about a $120 upgrade. To breathe new life into an older vintage radio that is less expensive than buying a whole new radio! The X-Lock-3 kit costs about $55 as delivered from the UK and is well worth the cost. The digital dial once set on frequency does not move. The HW-101 by itself was a well - designed radio for its time. The updating of the radio with the known circuit improvements and addition of some current technology now makes the HW-101 a modern radio.

73’s
Pete N6QW

The NorCal BLT Tuner

Thank you for buying the NorCal BLT antenna tuner. This kit has been around for several years, but recently I repackaged it, doing away with the pc board case and the Manhattan construction style in favor of a pre-drilled custom aluminum case. The case is made from very high quality .063 aluminum, and comes pre-drilled for all controls and connectors. This will make assembly much easier. There are two holes that you will have to locate and drill in the bottom of the case, but this is easy to do. Why didn't I have these holes predrilled? Well, by not doing so, the top and bottom of the case are exactly the same. This resulted in a significant savings on the cost of the case and kept the cost of the kit down.

And you have already found out that the manual is on a CD, instead of paper. This also helps to hold the cost down, and will allow me to make changes as needed. My thanks to Dave Fifield, AD6A, James Bennett, KA5DVS, George Heron, N2APB, Gene Sailsbury, N0MQ, and Paul Maciel, AK1P who all encouraged me to do so. Please check the American QRP Club Web page at www.amqrp.org for any corrections or additions to the manual.

CONTENTS *Click item to jump to desired section …*

Background

The tuner was designed by Charlie Lofgren, W6JJZ, who is renowned in the QRP World as a tuner expert. Charlie has built all of the tuners used by the Zuni Loop QRP Expeditionary Force for years, and they all swear by them.

This tuner is a balanced line tuner only, and will not work with coax feedlines unless modified as shown in the mods section at the end of this manual. It works great with open wire feeder, ladder line, zip cord and even computer ribbon cable. As long as you are using balanced line as a feedline, this tuner will work.

Charlie designed this tuner to work specifically with the polyvaricon variable capacitors that used to be available from Mouser. I asked him to design it at first because I wanted a simple tuner for a presentation that I was doing at the Ft. Smith QRP Group Forum, Arkiecon 2000. It turned out so well that everyone who saw it wanted one. Thus the NorCal W6JJZ BLT kit was born. I would like to thank Charlie for his efforts on behalf of NorCal. This one is going to be a classic.

The design is for a classic Z-Match, using inductive coupling with L1, L2 and L3 wound on a single T-106-2 toroid. L2 or L3 is switched in and out of the circuit by

Switch 2, located on the back panel of the tuner. The "high" and "low" positions on the switch for the output links may need clarification. The positions are for "high" and "low" in terms of impedance, not frequency. For a given band and antenna, try the High Z link first, and use the Low Z link only if a match can't be found with the high link. (Often either link will allow a match. In these instances, the High Z link produces better efficiency as a result of loading the tank circuit more heavily.)

The circuit also includes the famous N7VE LED SWR indicator circuit. Dan Tayloe invented this several years ago, and it has proven a great addition to the qrp fraternity. This allows us to have an indication of lowest SWR on the tuner (indicated by the dimming or LED going out at minimum SWR.)

The circuit also is an absorptive bridge, which means that your transmitter sees a 50 ohm load as you are tuning up. This will help to save your final transistors!! This tuner is rated at 5 Watts. I doubt if the polyvaricon caps will take the 100 Watts of your big rig!! Now, lets get started to build the kit. First of all, you will need the following tools: 25 – 30 watt soldering iron, drill, 1/8" bit, small Phillips screw driver, small blade screw driver, pliers, diagonal cutting pliers, needle nose pliers and about 4 feet of #24 solid insulated hookup wire. A Volt/ohm meter is helpful also. Please read the manual in its entirety before you start building. You may want to print out the schematic, parts layout, parts list and wiring diagram.

Building the BLT PC Board

Fig. 1 below shows the board as it comes in the kit. This type of board is called a Pittsburg Style board because the guy who makes them, Joe Porter, W0MQY, happens to live in Pittsburg, Kanas. Joe is a good friend of mine, and does excellent work. The Pittsburg board is similar to the Manhattan Style made famous by Jim Kortge, K8IQY, with the main difference being that all of the pads and traces have been etched on the board, so there are no pads to glue, and no wires to run. Both styles mount the parts directly to the copper, and use the remaining copper as the ground plane.

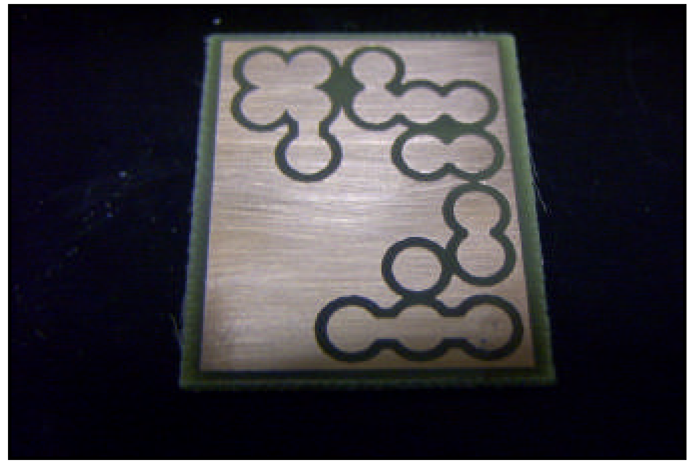


Fig. 1 – The Bare Board

The first thing that you need to do is to tin the pads as shown in Fig. 2. Prepare the board by scrubbing it with fine steel wool, or a scotch brite pad.

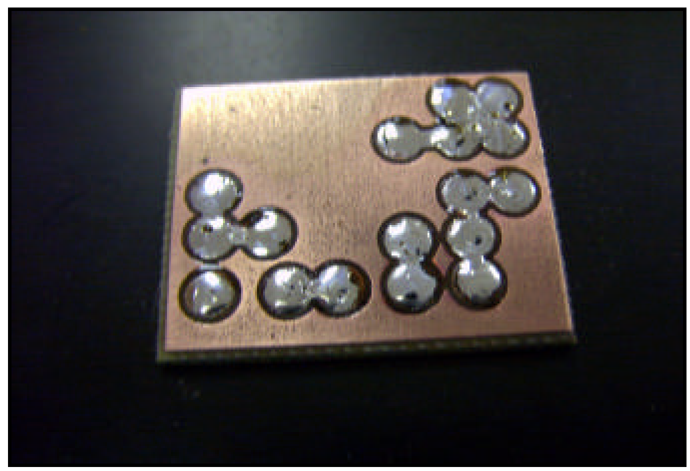


Fig. 2 – The Tinned Board

Fig. 3 shows the 2 pieces of #28 magnet wire, one red and one green, plus the small gray toroid. Unwind the wire, and straighten it out by running it between your fingers until the wire is straight.

Fig. 3 – Small Toroid + Wire

We will start the building process by windin a toroid that is used as transformer T1. It is easier to mount the toroid at this time because nothing else is in the way. You will use the red wire and green wire plus the toroid shown in Fig. 3.

Fig. 4 shows the toroid after the 25 turns of red wire have been wound. Start winding the toroid and count every timethat the wire goes through the toroid as one turn. This is the secondary winding of T1.

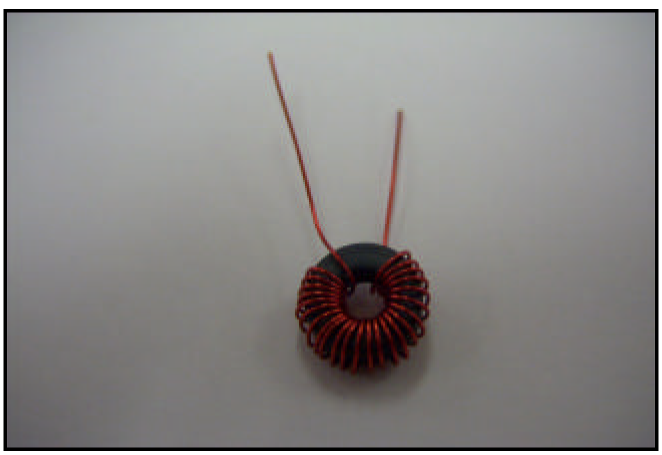


Fig. 4 – Toroid with 25 Turns of Wire

Next, take the strand of green #28 wire, and cut off a piece about 8 inches long. This will be used to wind the 5 turn primary of T1 over the 25 turn secondary. Wind the green wire 5 turns as shown and try to space it so that it is the same distance from the start and finish of the red wire as shown in Fig. 5.

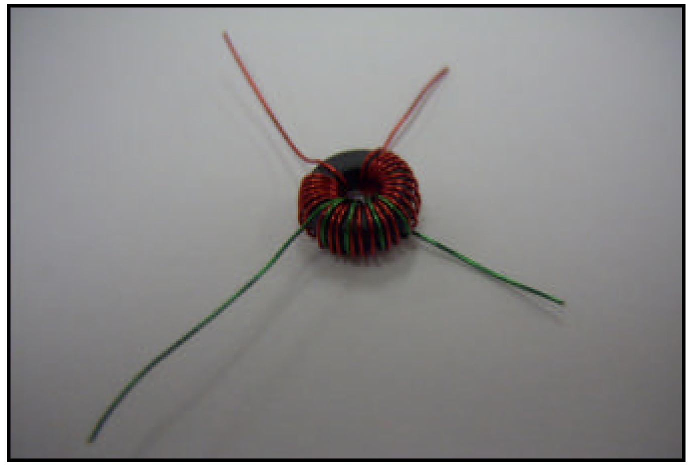


Fig. 5 – T1 with 5T Primary and 25T Secondary windings

The next step is very important. Be careful here, because this is where about 90% of problems with this tuner happen. You must remove the insulation on the four wires of T1 back to within 1/8" of the edge of the toroid. Don't worry it is easily done. Take a match, and burn the insulation off one wire. Be careful and don't get it too close to the toroid. Then, use some steel wool and clean off the burned paint until you see bright, shiny copper. Now, do the rest of the wires the same way. When you have all 4 wires cleaned, tin them using your soldering iron or a solder pot.

Refer to Fig. 6 to get the placement of T1 correct. Solder the green wires first as shown, and then finish with the red wires. Test the solder connections for continuity by using a VOM and placing the probes near the wire connections and seeing if you have continuity. If you do fine, if you don't, find out where the short is and fix it now while it easy to get to.

When you finish, the toroid should look like Fig. 6 below.

Fig. 6 – Toroid Mounted on Board

Next we will solder on the 6 - 100 ohm resistors. But first we need to prepare them. Take the first two, and prepare them as shown in Fig. 7. You will mount them on the pads for R2 and R2A.

Fig. 7 – 100 ohm Resistor ready to mount

Use Fig. 8 to figure out where R2 and R2A go on the board.

Fig. 8 – Resistors R2 & R2A Mounted.

Next we will prepare two more of the 100 ohm resistors, R3 and R3A. They will need to be prepared as in Fig. 9.

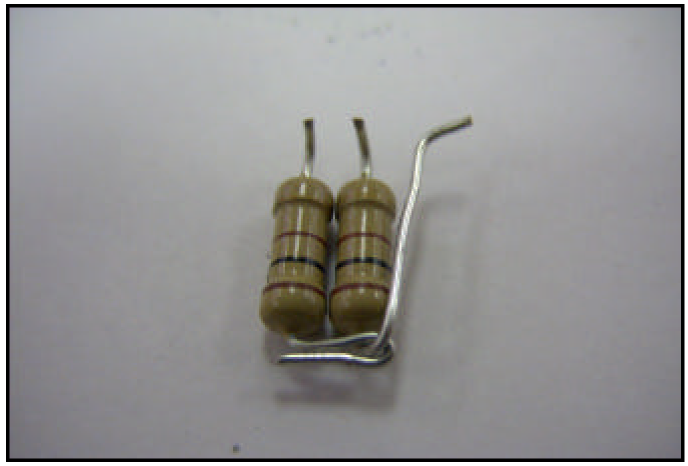


Fig. 9, Resistors R3 & R3A ready to solder.

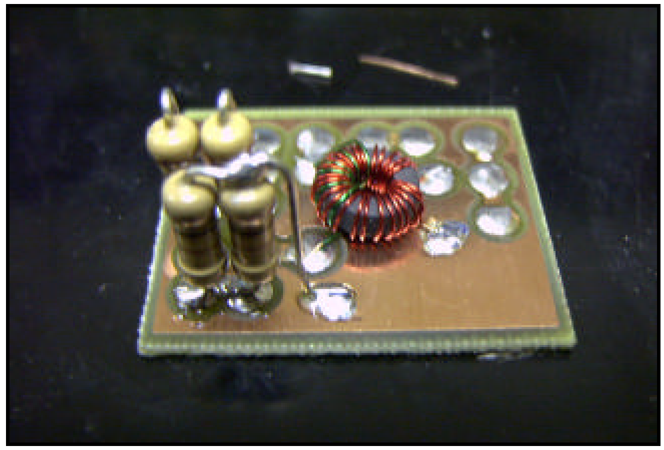


Fig. 10, Resisitors R3 and R3A soldered on the board.

Note that Resistors R2 and R2A are directly behind R3 and R3A in Fig. 10. Finally, prepare the last two 100 ohm resistors which will be R1 and R1A. Solder them on the board as in Fig. 11.

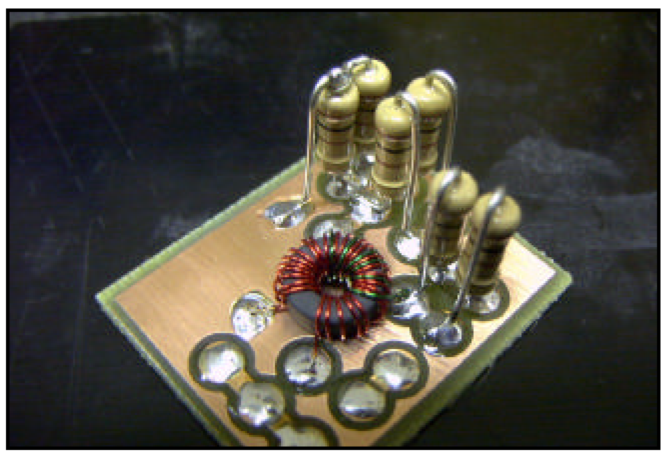


Fig. 11. Resistors R1 and R1A to the right of the toroid.

Prepare R4, the ¼ watt 1K resistor, brown, black, red, gold as you did the 100 ohm resistors, and solder in place as shown in Fig. 12, and on the parts placement.

Fig. 12 – R4 soldered in place just to the left of the toroid.

We only have 2 more parts to add to the pc board, the 1N34A diode and the .1 capacitor. Fig. 13 shows the diode after it has been prepared for soldering. Note the orientation of the black band and the way that the diode is prepared. Make sure that you do yours exactly the same way, and solder it on the board the exact same way as shown.

Fig. 13 – Diode D1 prepared for soldering.

After you prepare D1, solder it on the board as shown in Fig. 14. Make sure you do it the same way. It is a little bit hard to see in the picture, but the end with the black band goes on the middle pad, and the other end goes to the same pad that the red wire from the toroid goes to.

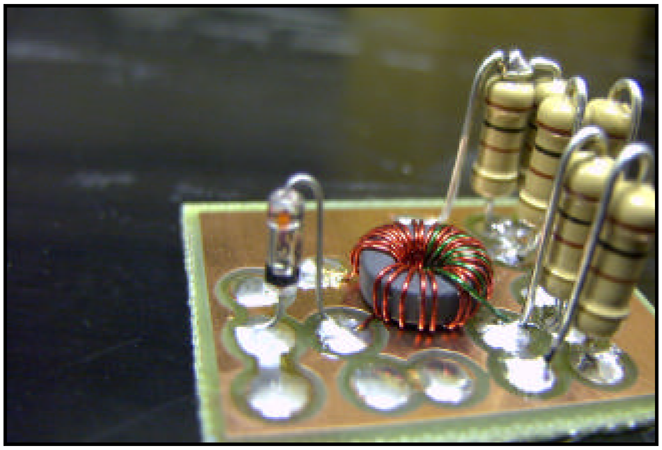


Fig. 14 – Mounting D1.

The last part to put on the pc board is the .1 capacitor, C1. Prepare C1 as shown in Fig. 15.

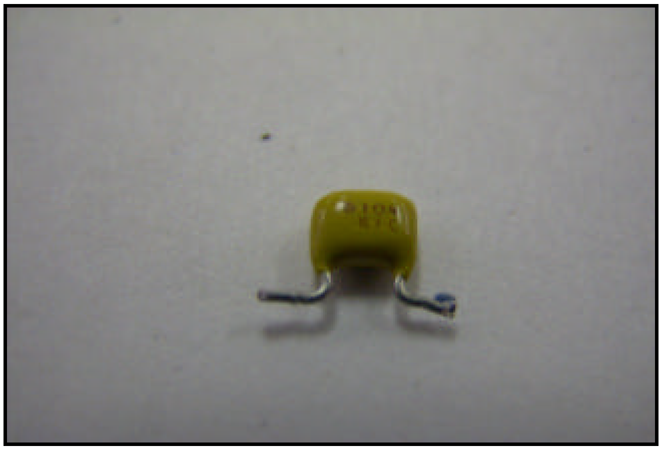


Fig. 15 – C1 prepared to solder.

Solder C1 on the board as shown in Fig. 16. Note that one end goes to the pad to the left of D1, and the other end goes to the ground plane.

Fig. 16 – Placement of C1.

Fig. 17 shows what the board should look like now.

Fig. 17 – The board after all parts are mounted.

Next drill a 1/8" hole as shown to be used to mount the board to the metal standoff. This is how ground is connected to the case, and you should make sure that you tighten the screws down tight. When you locate the hole be careful to not interfere with any parts on the board.

Fig. 18 – The board mounted on standoff.

Put the board aside for now, as we will assemble the case next.

Case Assembly and Parts Preparation

The case comes in four parts, a front panel, rear panel, top and bottom. The top and bottom connect to the front and rear panels by the ¼" x 4-40 flat head screws. Find the case and set it aside for now.

The first step is to prepare the two capacitors to mount to the front panel. Take one of the nylon spacers, and a 12 x 2.6 mm screw and attach the nylon spacer to the capacitor as shown in Fig. 19. The nylon spacer will become the "shaft" of the capacitor. I use a small drop of super glue between the nylon spacer and the capacitor to keep it from turning. Make sure that you don't get any on the capacitor shaft if you do this.

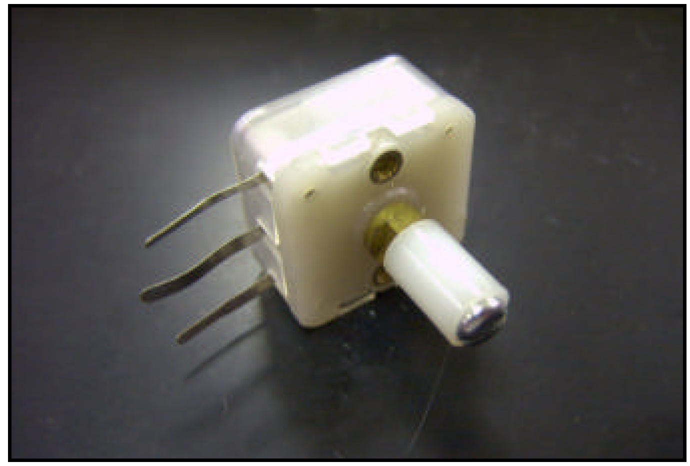


Fig. 19 – Variable capacitor with nylon spacer attached.

Find the other variable capacitor and prepare it the same way. Now find the 4 screws that fit the caps. They are small, round headed screws. Try one for a fit to make sure that you have the right ones. Attach both C2 and C3 to the front panel.

Now let's prepare the 2 switches. You will find 2 dpdt switches in the kit. Switch 1 goes on the front panel, and Switch 2 goes on the back. Find a resistor lead and use it to short the two pins of switch 1 as shown in Fig. 20.

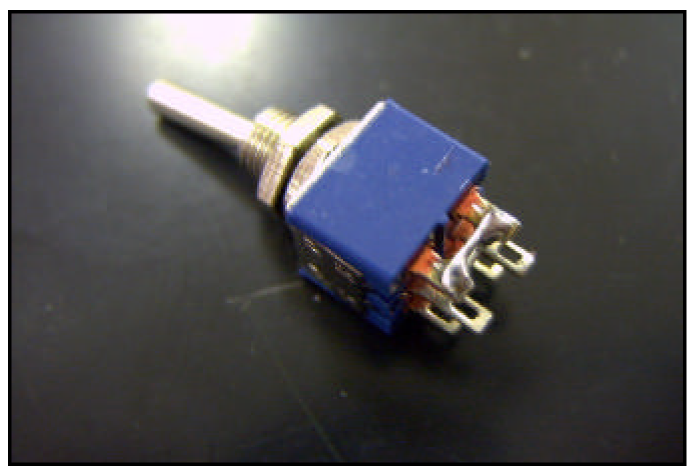


Fig. 20. – Switch one with the two pins shorted.

Be sure to solder the connections. Make sure that you don't hold the iron on the pins any longer than needed, as the pins are fragile and can melt.

Cut 4 pieces of solid insulated wire 4" long. I used some wire out of telephone cable. Connect them to the four remaining pins of Switch 1 as in Fig. 21.

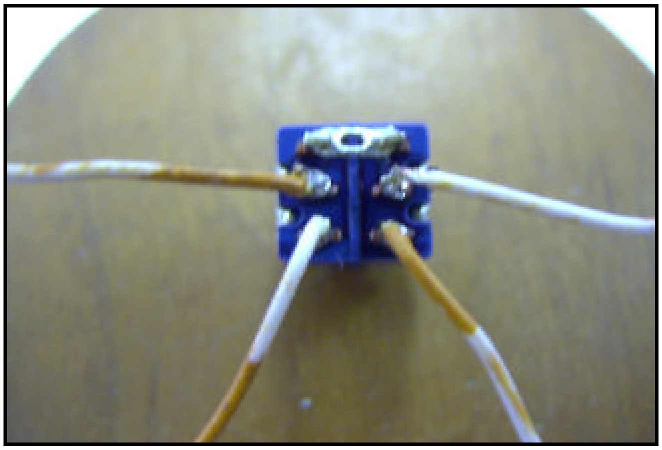


Fig. 21 – Switch 1 ready to mount on the front panel.

Mount Switch 1 on the front panel, making sure that the "jumper" is on the bottom.
This completes the assembly of the front panel except for the LED, which we will do later. Lay it aside for now.

Prepare 6 more 4" leads of solid insulated copper wire. Attach them to Switch 2 as shown.

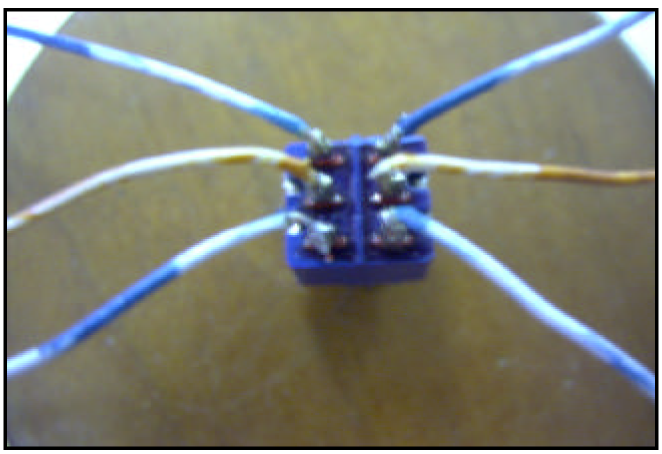


Fig. 22 – Switch 2 prepared for installation.

Find the back panel and install Switch 2 at this time. Then mount the BNC and the two binding posts as shown in Fig. 23. Make sure that you use a wrench or a pair of pliers to tighten the BNC and the Binding Posts. It is difficult to do after you have done the wiring. Note: If you intend to put in the unbalanced tuner mods, you should drill your holes in the back panel as indicated before you assemble it. See the mods section at the end of the manual. When you finish with the back panel assembly, set it aside.

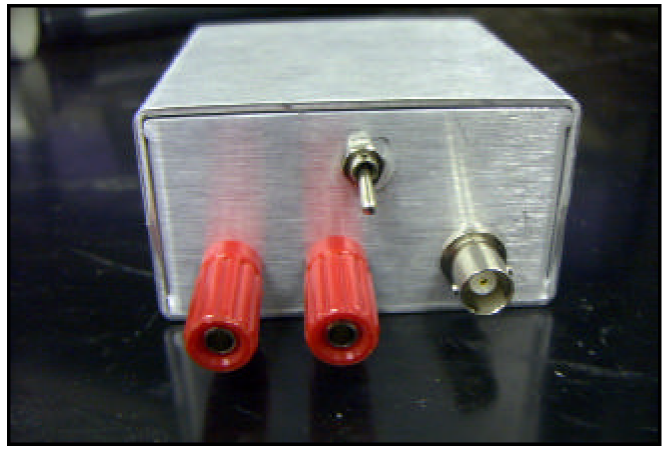


Fig. 23 – Back Panel

The last part to do is the big red toroid. It is really easy to do. Just follow the pictures. Remember that a winding or turn on a toroid is counted every time the wire goes through the hole in the center.

Fig. 24 – Red Toroid and Heavy Wire.

Start by taking a 30" piece of the red heavy wire. Fold it in half, and scrape the insulation off for a half an inch on either side of the fold. Then, twist the wires together as shown in Fig. 25.

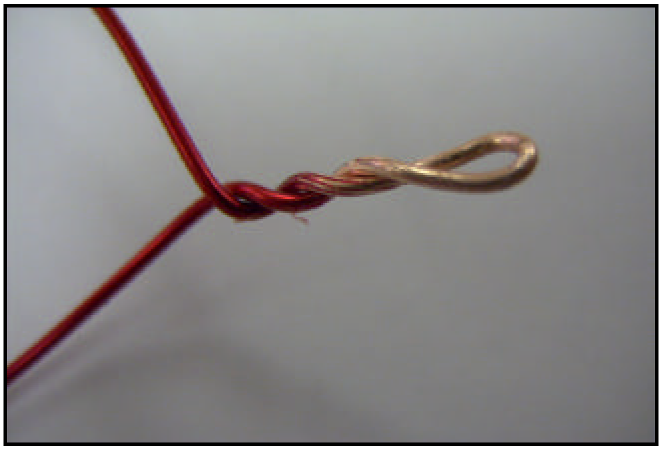


Fig. 25 – Twist in heavy wire.

First we will wind L1. Use the wire with the twist that you have just prepared to wind the 16 turns on the red core, starting in the middle with the twist against the core, and wind 8 turns in one direction and 8 turns in the other. Keep the same "sense" while winding, and you should end up with a core that looks like Fig. 25 after you have scraped the insulation off the ends of the wire.

Fig. 26 - L1 wound on the red core.

Now take another piece of the heavy wire, cut it 24" long and wind 12 turns, with six on a side of the tap in the middle. When you finish, scrape off the insulation and make a loop as shown. This winding is represented by the blue wire in this color version of the manual. You may chose to use different colored wire as I have, but you may also use the red wire provided in the kit. I used the different colors to show the windings better for this manual. See Fig. 27.

Fig. 27 – L2 and L1 both wound on the red toroid.

Note that the lighter wire is wound between the windings of L1.
Our final winding is L3. Cut a piece of wire 18" long and wind 6 windings around L2 and L1, with 3 windings on each side of the tap. It is represented by the orange wire in the color version. Be sure to scrape off the insulation and make the connecting loops.

Fig. 28 – The finished Toroid, note the tap on the right side.

Find the solder lug and solder it to the tap of L1 as shown in Fig. 29.

Fig. 29 – The large toroid prepared for mounting.

Put the toroid aside, and prepare to assemble the tuner.

Get the pc board. Locate it on the left side of the bottom of the case, mark a hole to mount the standoff.

Put the front and back on the case, so you will have plenty of clearance from the connectors and controls. Place the pc board as close to the left side as you can, but leave a gap of about 1/8" between the board and the side. My hole was 3/16" from the side and 1 3/8" from the front edge. Use the hole in the pcboard to mark where the hole needs to be drilled. Next, use a drill to drill a 1/8" hole in the bottom of the case. Do not mount the pcboard yet.

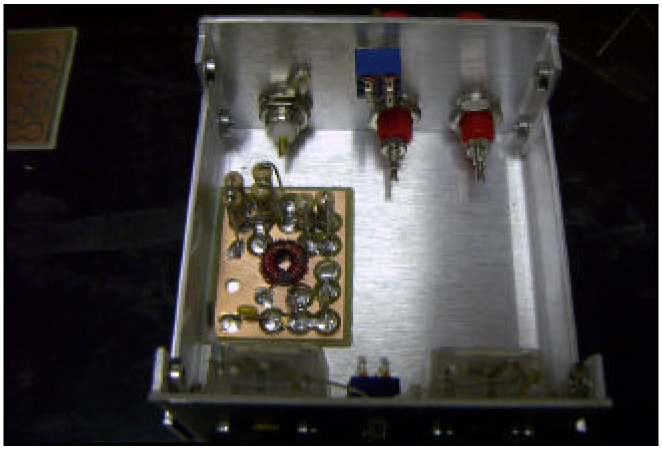


Fig. 30 – Placement of the pcboard on left side of case to locate mounting hole.

Next, with the back panel on, find and locate the hole for the big toroid ground lug. Mine was 3/8" from the back and right in the middle between the two holes for the binding posts.

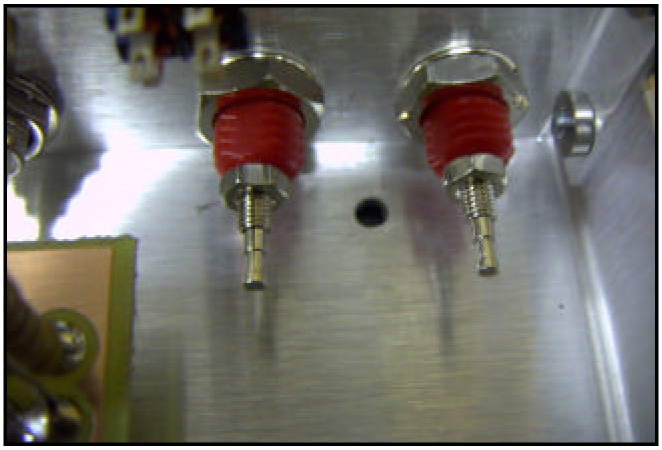


Fig. 31 – Location of hole for big toroid ground lug.

After you locate the hole, drill a 1/8" hole as shown in Fig. 31 above.
Next, use a 4-40 x ¼" screw and 4-40 nut to mount the toroid as shown in Fig. 32.

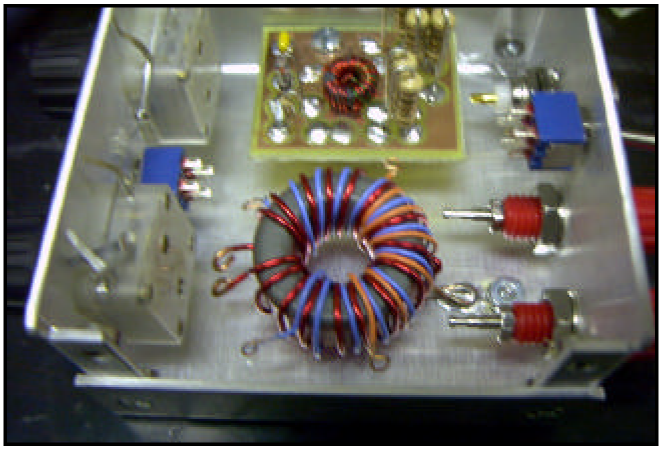


Fig. 32 – Large Toroid mounted by lug.

Use the mounting standoff, 2 star washers and 2 4-40 x ¼" screws to mount the pcboard. It is important to maintain a good ground connection between the board and the case. Assemble in this order.

1. **Place screw through bottom of case.**
2. **Put star washer on screw.**
3. **Put standoff on screw and tighten.**
4. **Put PC Board on standoff.**
5. **Put star washer on board centered over hole.**
6. **Put screw through star washer and pc board assembly to attach to standoff. Make sure that both screws are tightened securely.**

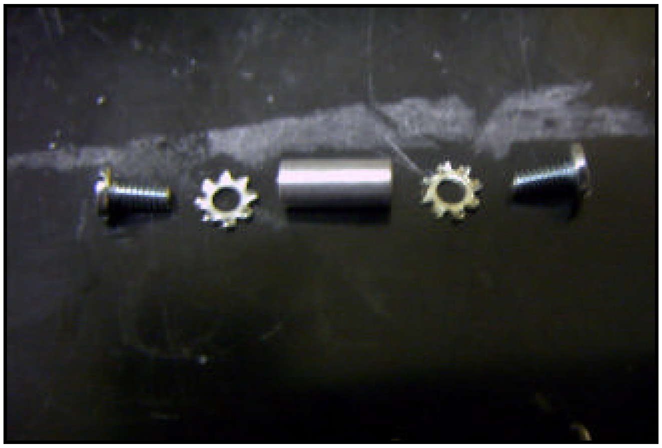


Fig. 33 – Stand off , screws and star washers.

Now we are ready to wire the tuner. Please refer to the wiring diagram in Fig. 34. I have drawn it in color to make it easier to follow. Wire as shown.

When you are wiring the LED, remember that the shorter leg of the LED is the one that goes to ground. Solder 2 wires about 3" long to the LED.You may use a spot of super glue to mount the LED in the case, but make sure that you don't get any on the lens. Mount the LED in the front panel, and then follow the wiring diagram to connect the LED to the proper places on the PC Board.

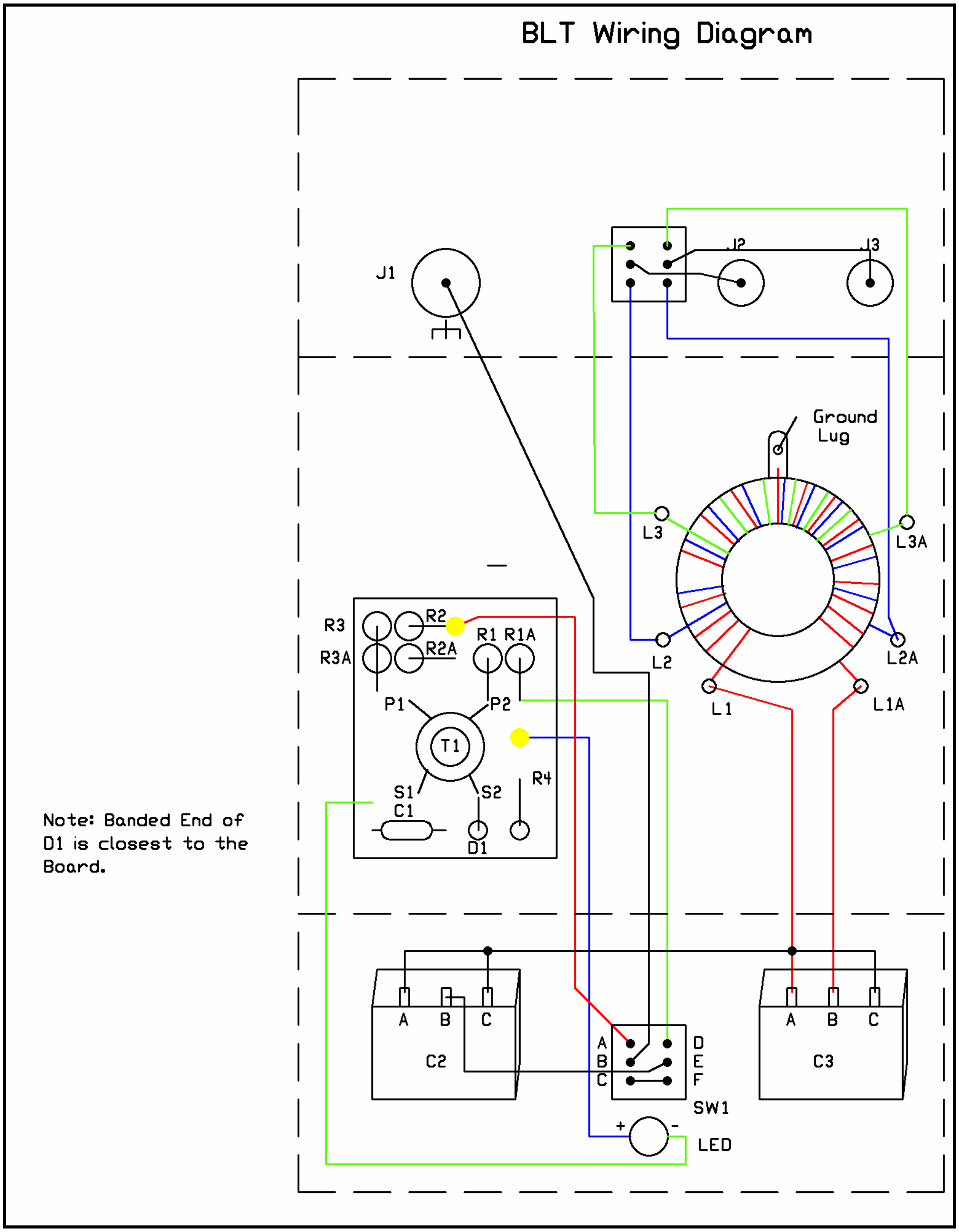


Fig. 34 - BLT Wiring Diagram

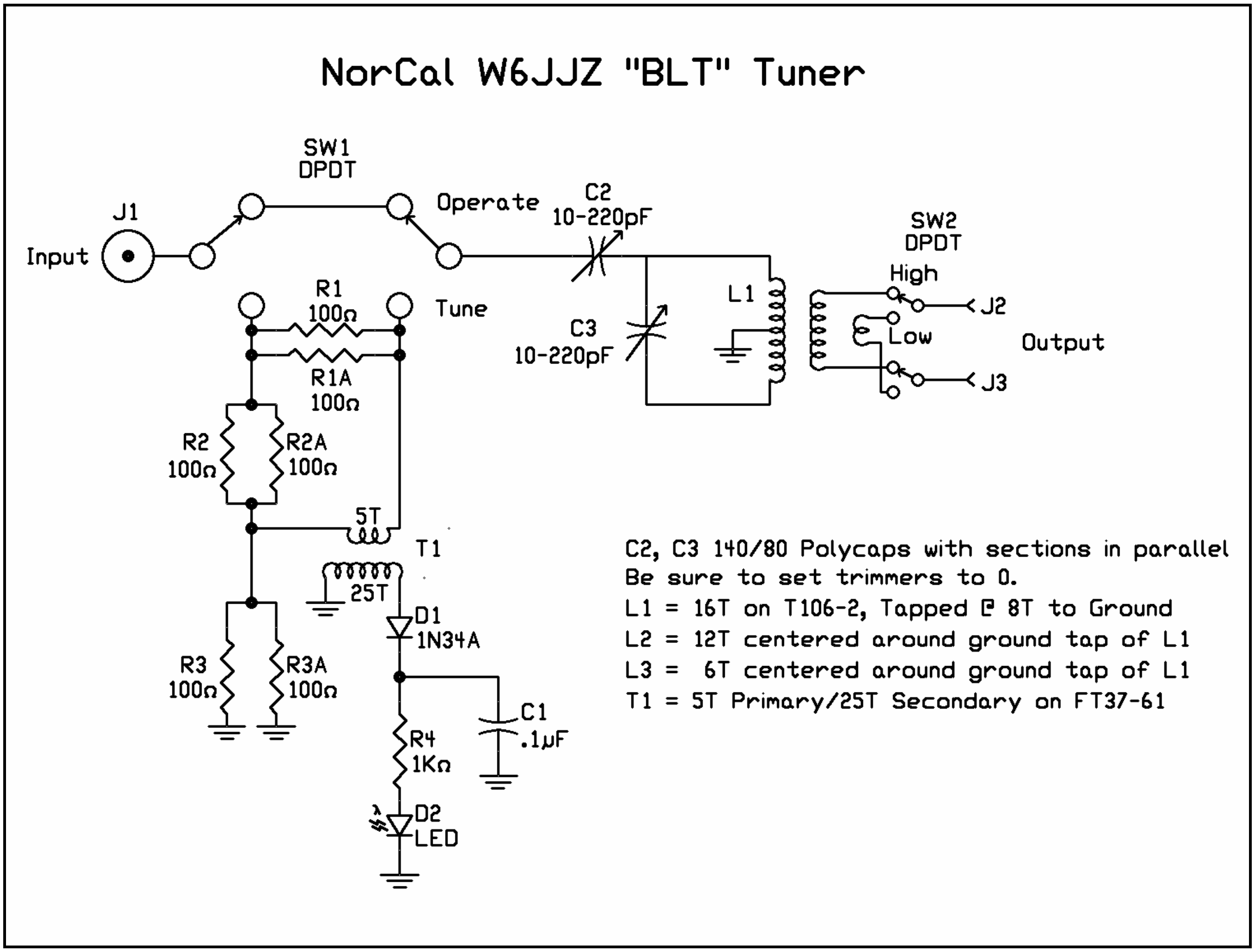


Fig. 35 – BLT Schematic

PCBoard Parts Layout

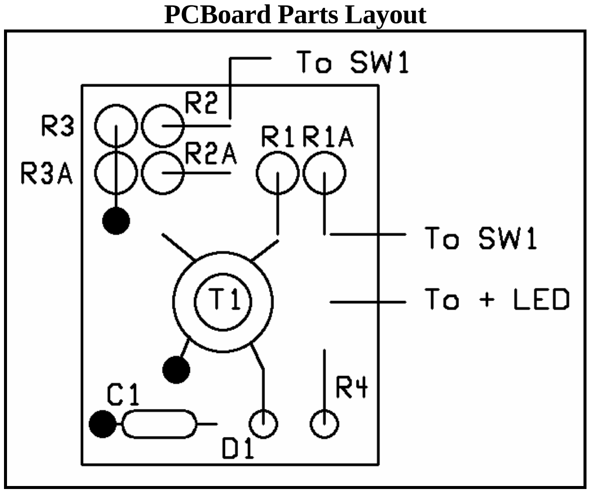


Fig. 36 – Parts Placement Diagram

Parts List

C1 = .1uF
C2, C3 = 140/80 Polyvaricons
D1 = 1N34A
D2 = Super Bright Clear Red LED
R1, R1A, R2, R2A, R3, R3A = 100 ohms/ 1 Watt
R4 = 1K/ ¼ Watt
SW1, SW2 = DPDT Toggle
J1 = Chassis Mount BNC
J2, J3 = 5Way Binding Post
L1,L2, L3 all wound on one T106-2 Core
T1 = 5T Primary/25T Secondary on FT37-61
4 x 4x2.6mm pan head screws
2 x 12x2.6mm pan head screws
2 x 3/8 Nylon Bushing
18" #26 Red Wire
18" #26 Green Wire
6' #22 Red Wire
2 Black Knobs
1 #4 Solder Lug
1 ½" Standoff
3 ¼" x #4 Panhead screws
1 – 4-40 Nut
8 ¼" x 4-40 undercut flathead screws
2 4-40 star washers
4 rubber feet

Mods:

If you want to use your tuner with a coax fed or long wire antenna, a simple mod makes it possible. It involves drilling 2 new holes in the back panel, and adding a single pole switch and another BNC. Here is a picture of the back panel with the new holes drilled. I drilled mine 3/8" to fit the BNC, and you will have to determine the size for the switch based on the switch that you use. By the way, the parts are available at Radio Shack if you don't have them in your junk box.

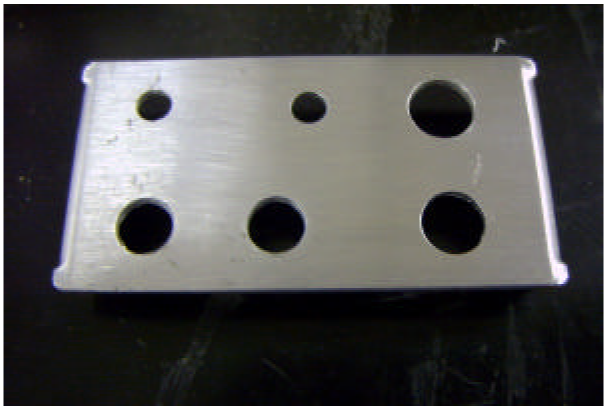


Fig. 37 – Back Panel with mod holes drilled. After you drill the holes, mount the parts. It should look like the picture below.

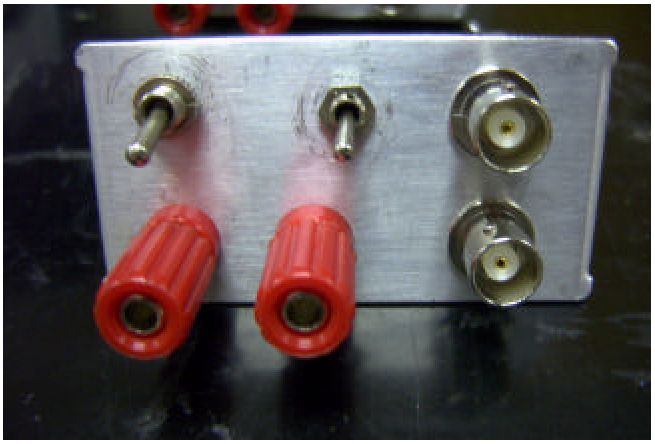


Fig. 38 – Back Panel with mod parts added.

The wiring is simple. The photo below shows the additional wiring that you have to do for the mod. You still have to wire the tuner as per the main wiring diagram, but I have left those wires off to illustrate the added wiring for the mod. Note that you may also go to the solder lug of the big coil for ground, I chose to use the solder lug on the BNC.

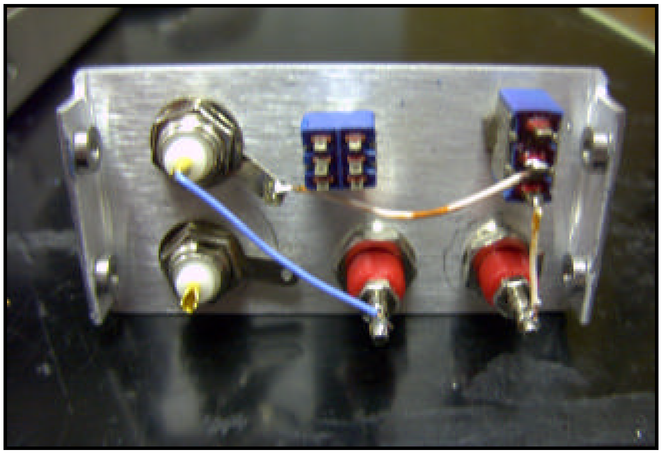


Fig. 39 – Wiring diagram of additional wiring needed for mod. Note that the normal wiring is not shown in the picture for clarity.

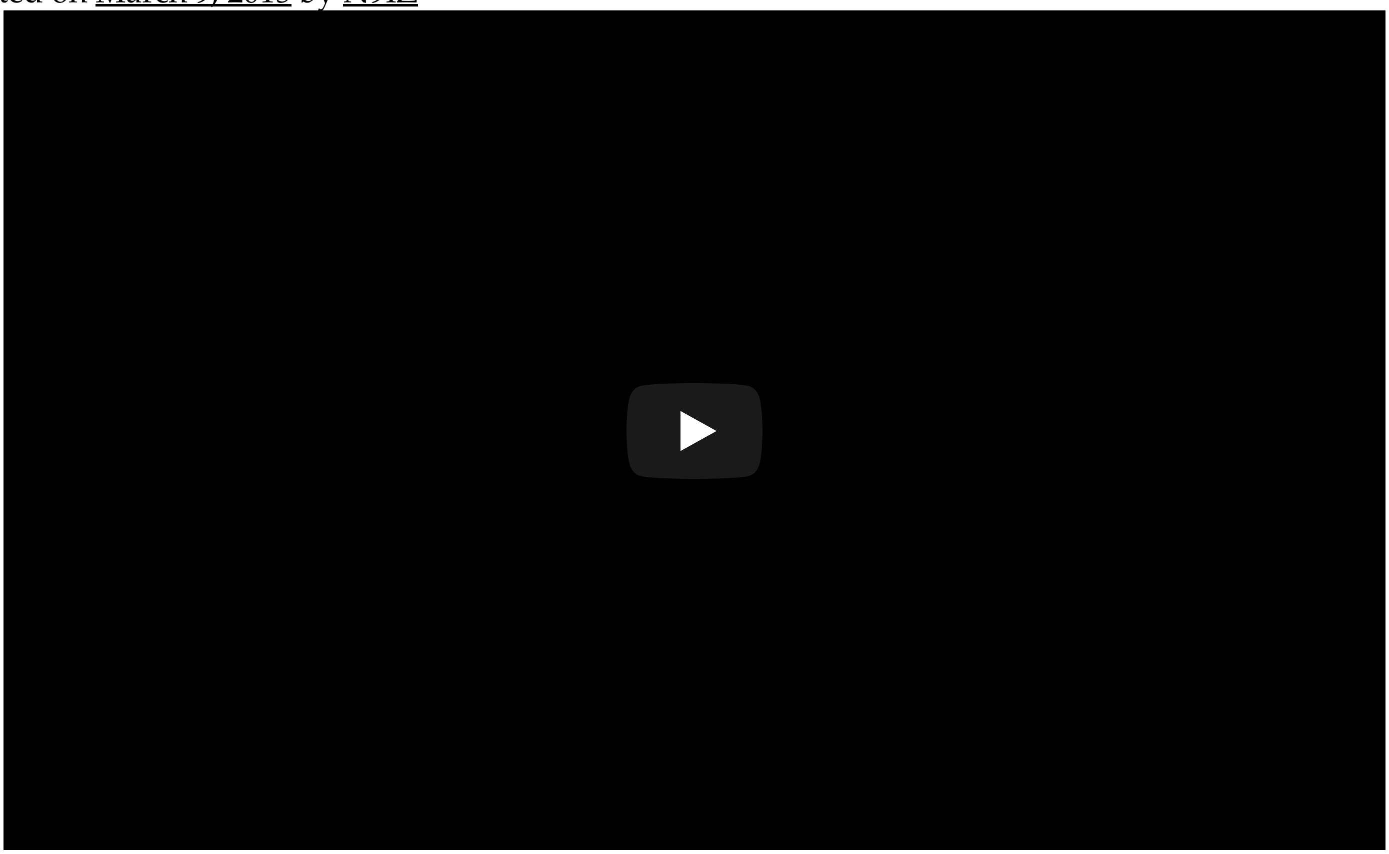
To operate the tuner as a long wire or Coax fed tuner, all that you have to do is switch the added switch in, which will ground one of the binding posts. Now the tuner will work with either coax or long wire. Be sure to connect the long wire to the center binding post, and the counter poise if used to the outside binding post. Also, don't forget to return the switch to normal off position when you are using the tuner in the balanced configuration

N9IZ Amateur Radio Blog
Launching RF into the Ether since 2001

Posts Tagged With: michigan mighty mite

THE MICHIGAN (INDY) MIGHTY MITE

Posted on March 9, 2015 by N9IZ



Most of my ham friends know I've been a devoted listener of the SolderSmoke (http://soldersmoke.blogspot.com/) podcast for some time. Bill Meara N2CQR and Pete Juliano N6QW make a great team discussing the building and operating of all manner of homebrew, boatanchor, and QRP gear. Their enthusiasm is obvious and they really give the listener a sense of confidence that it just might be possible to really build something yourself in this modern age.

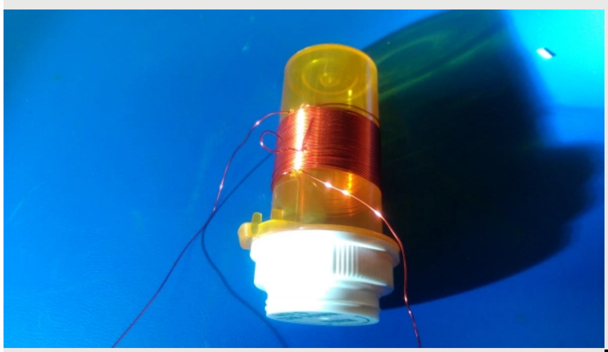
Building components and constructing circuits is to me the essence of ham radio. I've built small kits like the N0XAS Pico Keyer from Ham Gadgets (http://www.hamgadgets.com/index.php?products_id=89) and similar odds and ends, but never any "real" ham gear. I'm kinda like the average Joe that watches the home remodeling show on TV and thinks it's cool to restore the 100 year old house, but lives in a newer house with little maintenance. It all sounds glorious, but you have no idea where to start.

Enter the Michigan Mighty Mite (http://www.qsl.net/wb5ude/kc6wdk/transmitter.html). This simple transmitter requires only seven components and produces around 500 mW RF output. To up the ante Bill sent out the necessary 3.579 MHz colorburst crystal for free to anyone who emailed him a request and promised to use it. Pete built the circuit and added some pro tips (http://soldersmoke.blogspot.com/2014/11/pete-builds-michigan-mighty-mite.html) of his own on MMM construction on the blog. Now this seemed to be a project I could handle! I fired off an email in short order.

 (https://n9iz.files.wordpress.com/2015/03/3-579-crystal.jpg)

My crystal got torqued by the USPS!

What arrived was something of a disappointment. Evidently USPS sorts mail with a steam roller. My precious crystal looked like momma worked it over with a rolling pin! This depressed me enough that I delayed building the transmitter for some time. I panicked and purchased a whole bag of crystals, just to be safe. Eventually I turned up some magnet wire, a pill bottle and the necessary capacitor and resistors. The remaining air variable cap was ordered from Amazon (http://www.amazon.com/). Turns out they have all manor of useful materials, who knew?

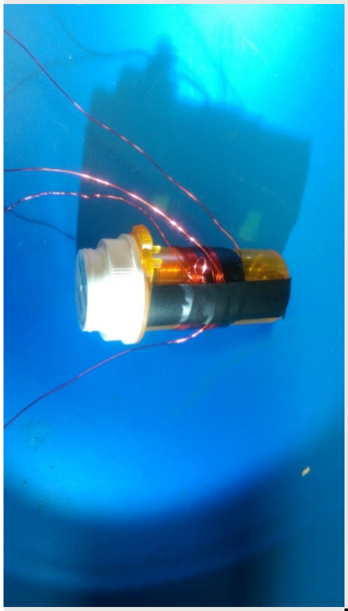
 (https://n9iz.files.wordpress.com/2015/03/first-winding.jpg)

First winding with tap.

The hardest part was winding the coil. That wasn't too bad, though. I held it together with tape. Everything was assembled on a bread board for trial. I must admit to being overjoyed when I saw the visual waveform on the PowerSDR panafall display of my Flex-5000A main shack radio. So much so, that I ran through the house calling for my YL, KC9TAH. She was in the shower and thought I'd cut off a finger or something while in the mad scientist lair. Much to her dismay, it was only a nasty CW signal emanating from the Flex speaker. She did humor me by going out to see the marvelous project before asking me what I was going to fix for lunch.

So where do I go from here? I have a small piece of perfboard on the bench. I guess I should assemble it on that in a proper arrangement. My friend Brian KB9BVN has requested a QSO but I'll need to build a low pass filter to knock down the harmonics. No sense of incurring the wrath of the FCC and

homebrewers everywhere. My next project is a small regen receiver and the Ugly Weekender and Ugly Weekender II combo. Both of these come from old issue of *QST*. I have the circuit boards from Far Circuits (http://www.farcircuits.net/) and plan to build them with the boys. Might as well infect the next generation with a case of "the knack" if at all possible.


(https://n9iz.files.wordpress.com/2015/03/second-winding.jpg)
Second winding over the first goes to antenna and ground.

(https://n9iz.files.wordpress.com/2015/03/cbla_logo.png)
Join the revolution!

Categories: Activities, Amateur Radio, Projects | Tags: amateur radio, ham radio, homebrew, michigan mighty mite, qrp | 2 Comments

Blog at WordPress.com.

DIY Audio Home

"La Luxuriante" R120 SE stereo amp

Well, this is a little bit of a long story...

Years ago, through some horse trading, I wound up with a couple of R120 triodes. The R120 is a rare IDHT made (mostly?) by RT in France. It is very highly regarded in some circles (especially in Japan) for it's sound. You can find data on it here:

http://www.mif.pg.gda.pl/homepages/frank/sheets/084/r/R120.pdf

Just by reading the datasheet you would probably find it... uninspiring. Not only that, but if you examine the tube's construction carefully, it has a screen grid inside, which is connected to the plate. I've never heard if this is the same as some other (available and maybe less expensive?) pentode...

I wound up putting the R120's into the SE 829B amplifier (this one) in place of the 829B's. This amp uses a pentode first stage DC coupled to a cathode follower to drive the output tubes, and no NFB. I measured it, and was... uninspired. It has quite a lot of 2nd order distortion, more than a similar 300B or 2A3 amp. I listened to it a little, but wound up putting it on a shelf.

A few years go by, and Dick Olsher (who writes a lot of reviews in Stereophile, The Absolute Sound, etc.) contacts me. It turned out he had gotten another amp that I built, and it stopped working. I asked him if he wanted to try the R120 amp that I had sitting around, and we eventually made it a permanent trade, the R120 amp for the other amp.

Dick really likes the R120 amp. He uses it as a reference to review other amps. I even have people contact me from time to time and ask me about this "magic R120". I figured that since R120 tubes are pretty rare, I'd probably never see any more.

Last year at the 2014 European Triode Festival, I see some single-ended output transformers on the "flea market" table that look very nice. They're made by Yves Monmagnon from France - Dissident Audio DA-143, to be exact. You can find the datasheet here: http://www.dissident-audio.com/SE_300B/KISS/DA143-a.pdf

In general I had decided I'm not a great fan of SE amplifiers, after building quite a few of them. But these OPT's looked like a good deal, so I wound up taking them home.

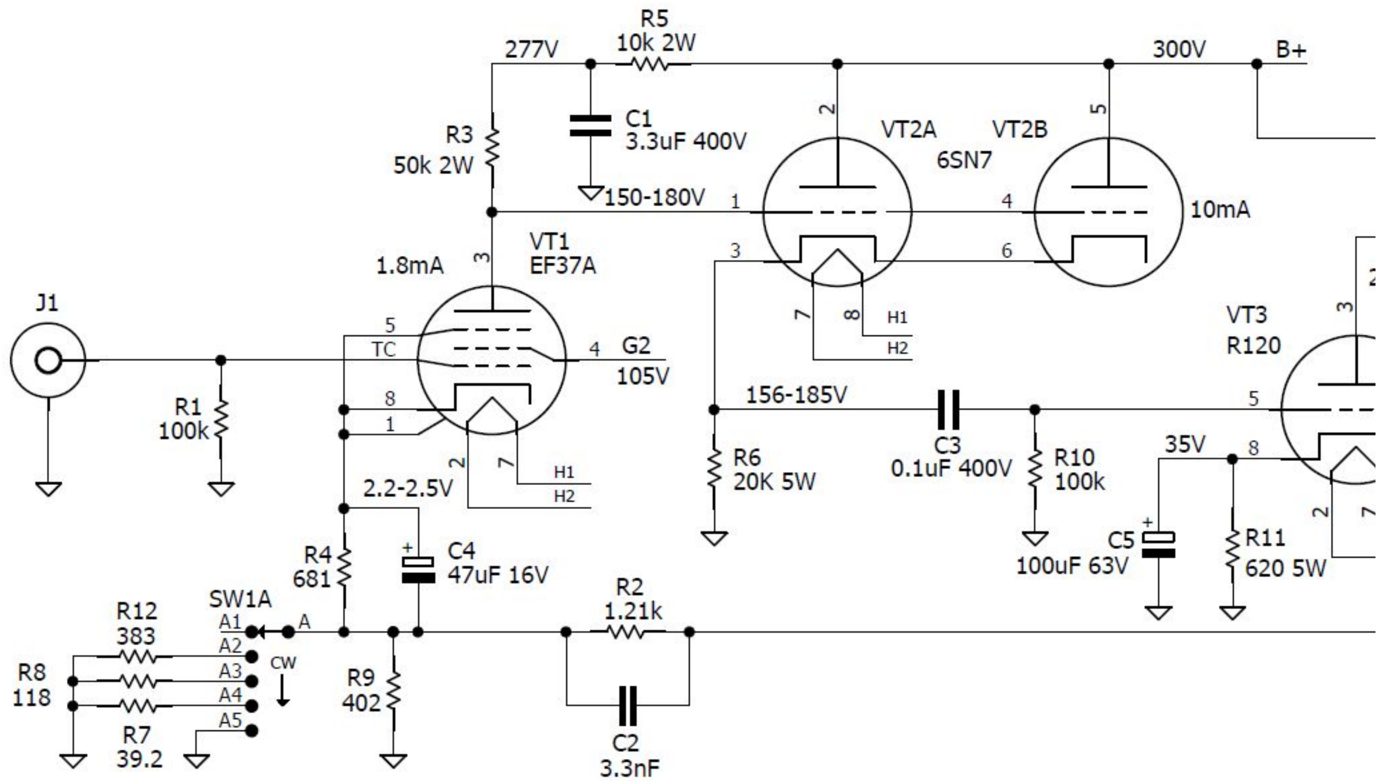
Over the next year, from time to time I see these OPTs on the shelf, and breadboard an amp with it. Nothing ever really struck me as worth making into a real amp.

Fast forward to this year's past ETF... what do I see on the flea market table? A bunch of R120 tubes, with a very attractive price tag. And it turns out that the person who brought them owed me a little money from something, so a little more horse trading and I come home with some more R120s.

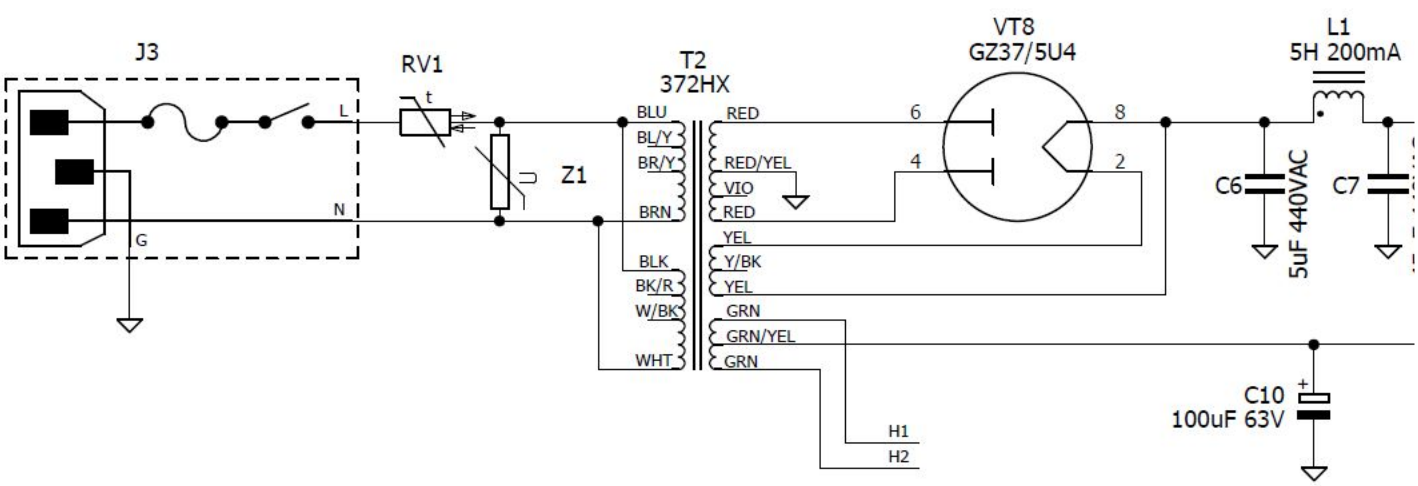
Perfect - I have a great French OPT and some great French triodes - I will build an amp with these! I even have some French EF36's to use as input tubes.

From the onset, I expected that I would wind up selling this amp. I was convinced that SE amps just aren't my thing. I am no longer convinced.

The design is basically the same as the original 829B-cum-R120 amp. I used the same pentode direct coupled to triode cathode follower circuit. The R120 is run close to the datasheet operating point of 250V and 60mA. I added a provision to apply adjustable global NFB - or not. This tamed the distortion a little bit and lowered the Zout, and improved the low frequency response a bit. Here is the amp schematic:



I did start from scratch with tuning component values, and used a somewhat better power supply design. B+ uses a GZ37 (or 5U4) rectifier, common CLC filter plus a separate LC filter for each channel. Using a Hammond 372HX power transformer, B+ came out spot on the simulated result of 300V. The input pentode screens are supplied by a VR tube shunt reg.



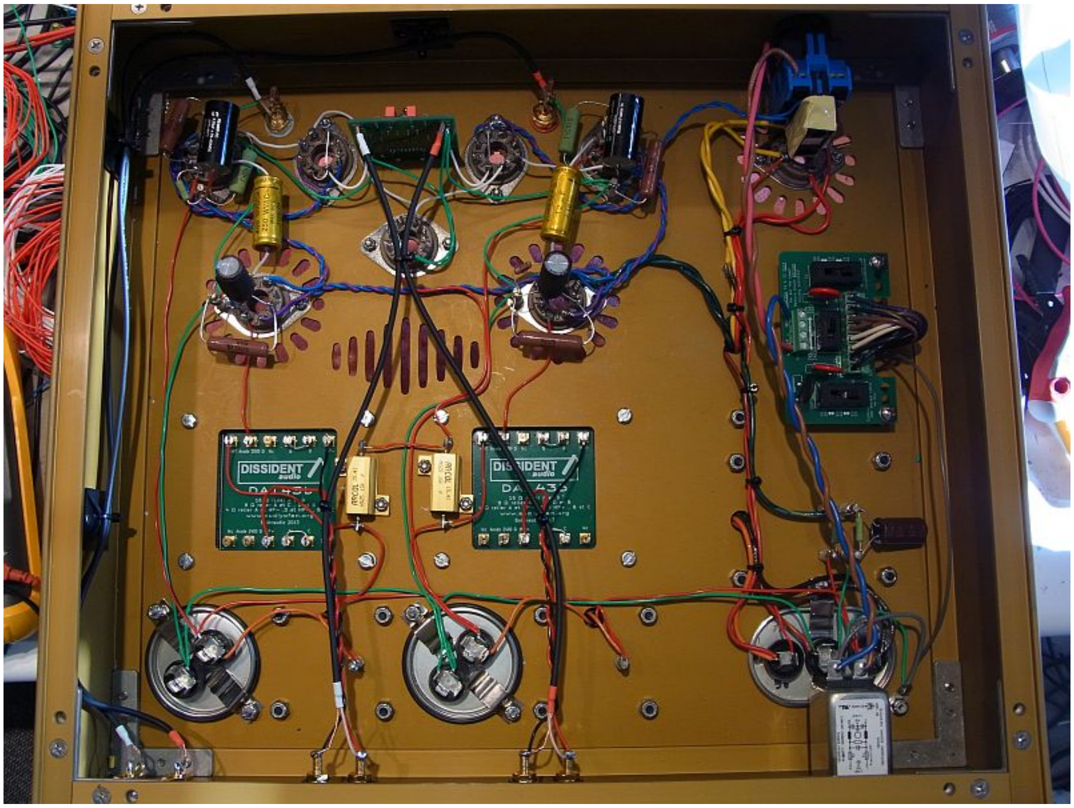
Here is the [whole schematic in PDF form.](http://www.pmillett.com/r120_se_amp.html)

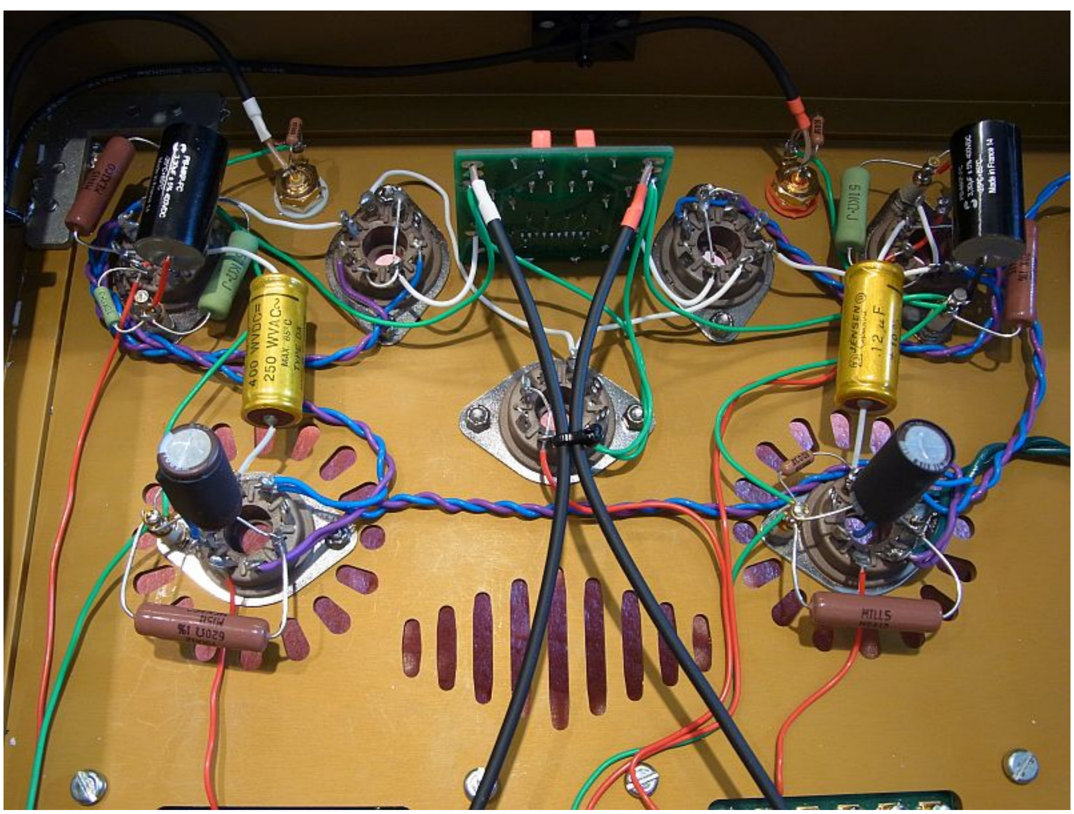
By the way, this same front end circuit can be used with 2A3 tubes with very few changes, or triode-connected 829B's or EL34's or whatever. Even 300B's if you bump up the B+ a bit - then it is almost a WE91A with a cathode follower inserted.

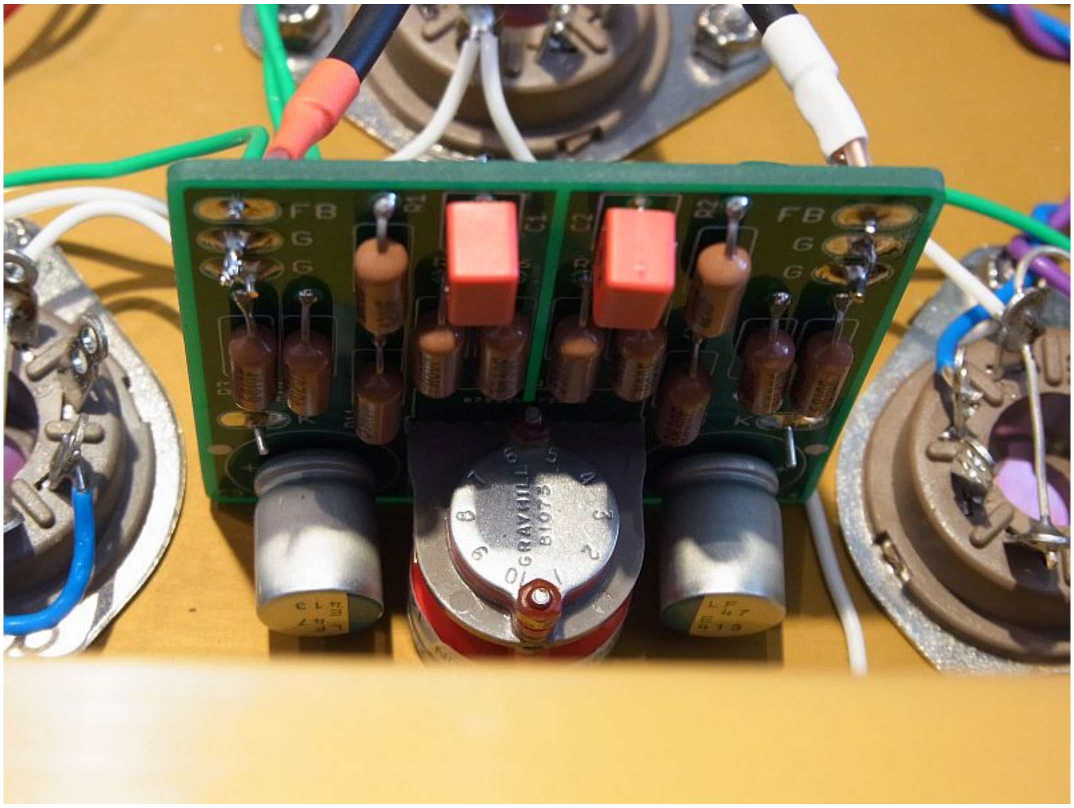
You can use any number of pentodes in the front end, EF36, EF37, 6J7, 6SJ7, 5693, 6C6, 310B, 348A, etc. The cathode follower can be anything 6SN7-like, or other triode if you change the cathode load resistor to set the plate current and dissipation to something reasonable.

Construction is all point-to-point mostly on the tube sockets, with a few single-point terminals used here and there, with two exceptions: to implement the adjustable NFB, I made a small PCB that carries a rotary switch and the resistors used in the cathode circuit of the input stage, and I also made a small PCB to take care of voltage selection on the multi-primary Hammond 300-series power transformer.

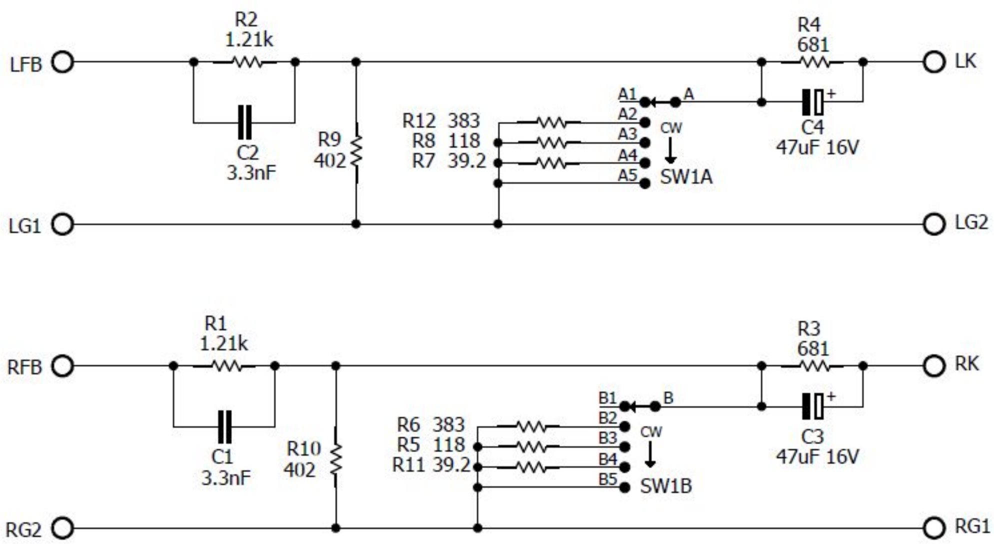
The chassis is another nice one made by [Landfall Systems.](http://www.landfallsystems.com) They did all the machine work and engraving for me.





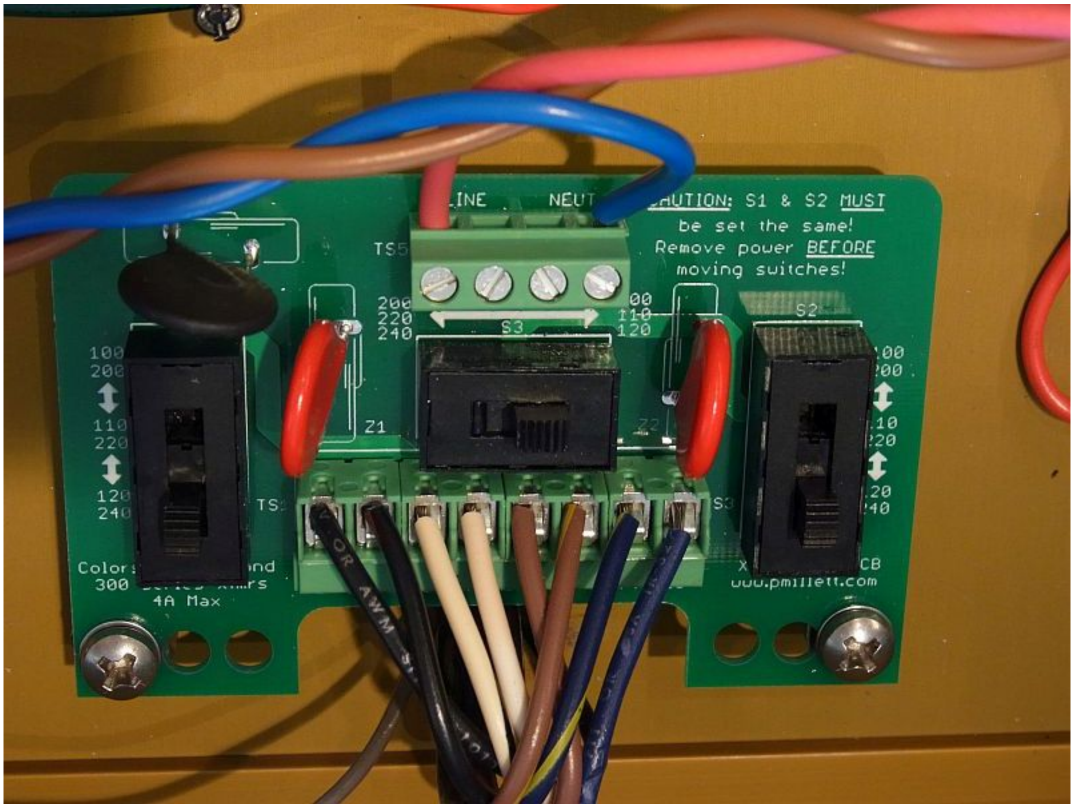


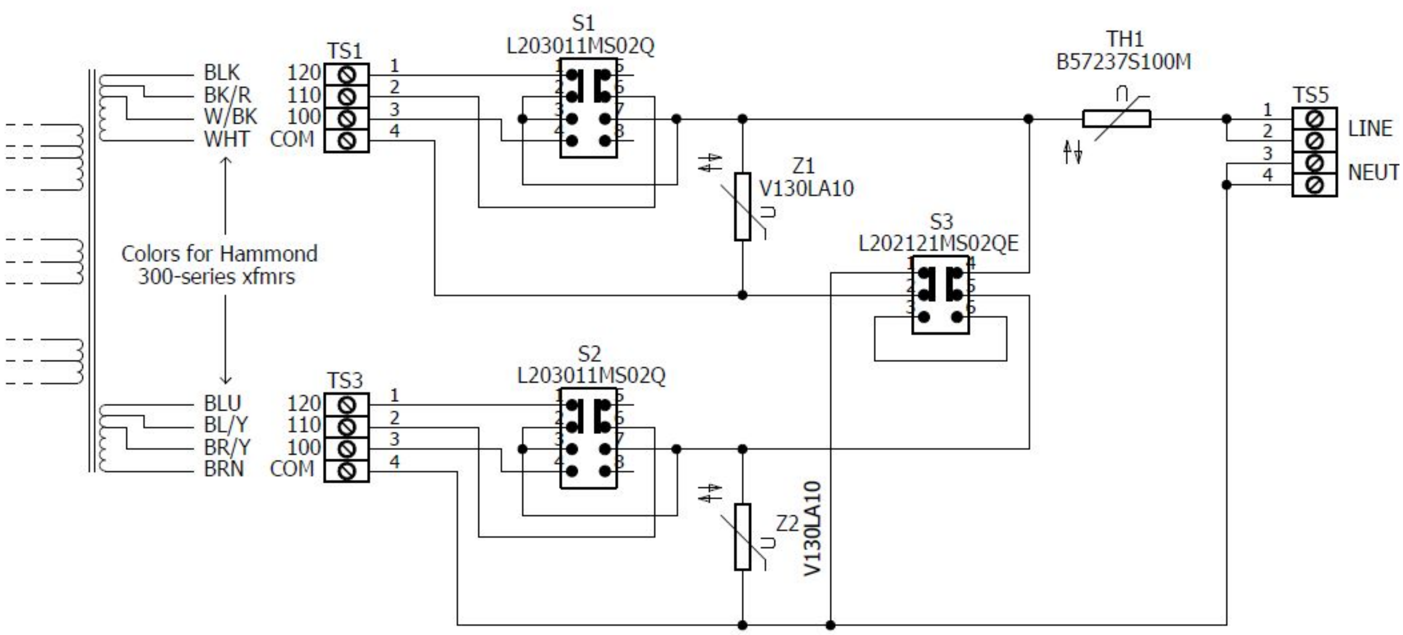
Here is what's on that small PCB:



Yes, it does move the input tube bias point a bit when you change the feedback setting, but it's not enough to make a big change. The way the resistors are set up it's even safe to switch this while the amp is on - it makes a modest pop in the speakers but nothing too frightful.

The voltage selector for the power transformer uses some slide switches to allow you to configure the line voltage to 100, 110, 120, 200, 220, or 240V. I know, not really necessary, but I always hate having all those extra wires not connected to anything. The board is designed to mount to two of the transformer's mounting screws. It also provides a good place to put MOVs and an inrush limiter. And besides, if I sell it, who knows where it will go...





I fabbed a bunch of both of these PCBs, so will probably wind up selling them. Contact me if you are interested.

So, I finish the amp up and do some testing. Unremarkable - about what I expected. It will put out about 4.5 watts into 8 ohms at 5% THD, depending on the NFB setting. THD at 1 watt is more than 1% with no NFB, and still substantial with NFB dialed in. I expect it to sound OK, but still sound like the other SE triode amps I've built.

But it doesn't, and I don't know why.

Maybe there is some magic in this OPT?

Anyway, I started off with the amp driving some BG planar speakers. It sounds pretty good Vocals, especially female, have a different clarity, and transients have a very live sound. The bass response is surprising. I turn off the subwoofers, and it actually sounds a little better. But with 4.5W it doesn't play very loud before it gets a bit muddy.

Next I try with a pair of ~90dB/1W efficient open baffle speakers that use a 15" woofer and a Fostex full-range tweeter, sort of a combination of Martin King's OB speaker and John Busch's Manzanita speakers.

Wow, this is something special. The bass response is amazing, even with no NFB - clearer than I'd ever heard from an SE amp. And the transient response - clarity of things like a drum stick hitting the rim, and again vocals - were really impressive.

I have more listening to do, but for now, I'm impressed and surprised. Not sure if I can sell this or not...

DIY Audio Home

Isolated Current Sensor for PanelPilot Digital Panel Meters

Normally, when you want to measure plate current, you just stick a small resistor in the cathode circuit, and measure the voltage drop across it. But I'm working on a push-pull amp using the 815 tube. The 815 is a dual beam tube, with a common cathode and G2 connection. The 829B and several other transmitting tubes share this "feature".

I'm using fixed bias, and driving it in A2. So I really wanted to be able to independently measure the plate current through each side of the tube. I was reluctant to put any kind of meter directly in the high-voltage (600V in this case) B+ path. So I started looking at isolated current sensors. Note that this type of sensor works equally well in the cathode circuit.

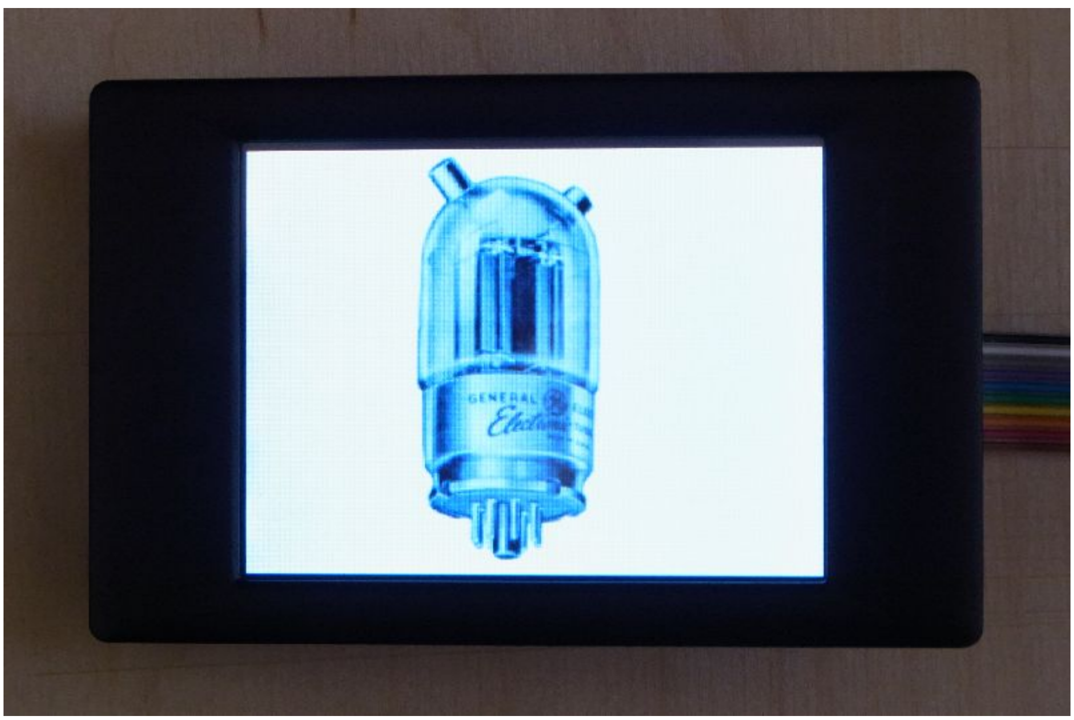
There are lots of isolated current sensors available, using different technologies, with widely varying price and performance levels. I decided to go with a relatively inexpensive uncalibrated sensor from Honeywell, the CSL series. This is a hall-transducer based, "open loop" sensor, available from DigiKey or Mouser for about $15 each. This particular model (CSLW6B1) gives a DC output of about 1V/A, or 1mV/mA. Current is sensed in a small coil of wire (60 turns) wrapped around a ferrite core, which directs the flux across a Hall sensor element. This introduces a little resistance (160 milliohms) and a little inductance, but it's pretty insignificant in a tube amplifier circuit. Strangely Honeywell does not provide an isolation voltage rating, but looking at the thick plastic bobbin that the coil is wound on, I would thing it's good for more than 1kV. Most line-voltage stuff needs 1500V isolation...

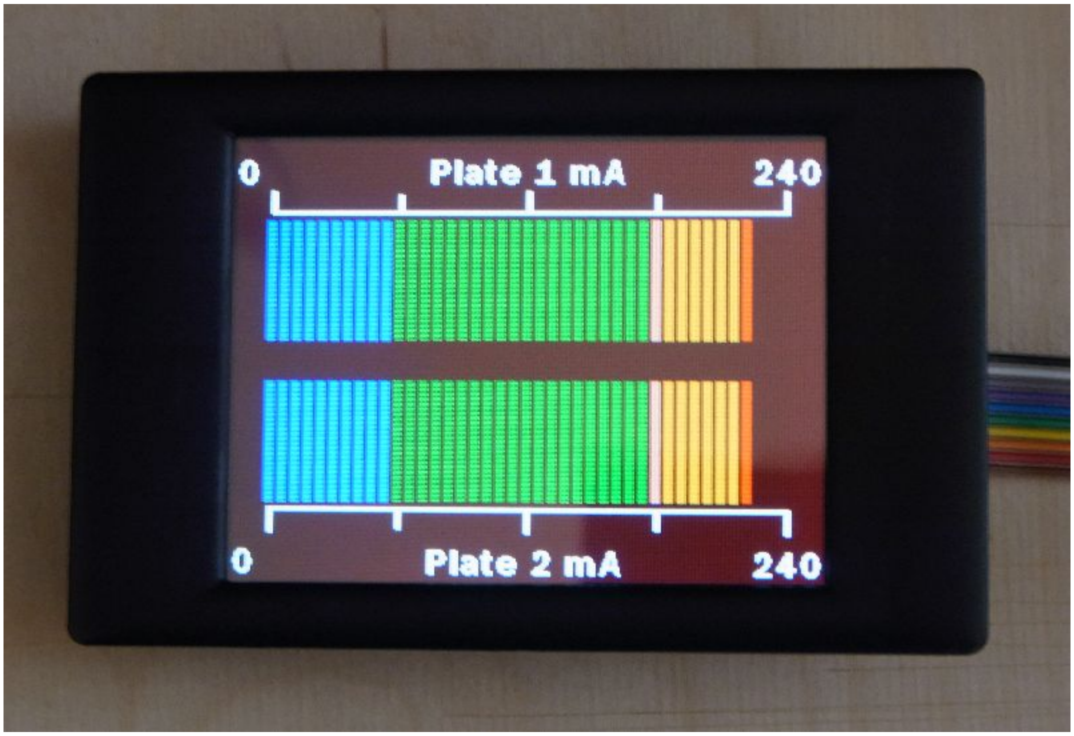
OK, so I found a sensor. It requires a DC supply voltage of 5V. It's also not calibrated in terms of zero-current output voltage and gain; both can vary by ~10%. So I needed to provide a circuit that can allow adjustment of these parameters. Then I can output a calibrated voltage that's proportional to the current through the transducer.

Along the way I started looking at meter options. I thought it would be way cool to have a little LCD display that could be programmed as a multi-function panel meter. I almost started designing such a thing, until I found this:

This family of devices (which comes in a number of different sizes) is made by Lascar Electronics, and is programmed using a free piece of software called PanelPilot. You can see compatible products (which come in a number of sizes) on the PanelPilot site. A cool interactive demo explains the features.

You get to choose the display presentation, colors, scaling, text, labels, and even download a splash screen image to the meter! One or two inputs are supported, so in my case, I used two channels to display the plate current for each side of the 815 on one display:

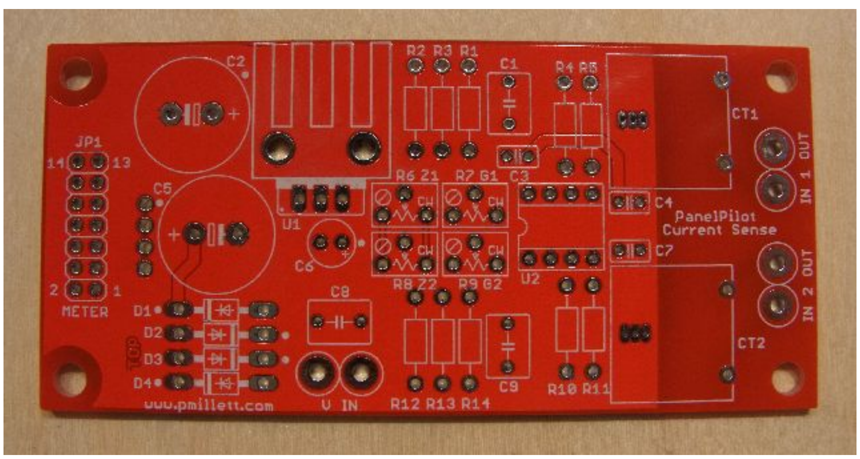


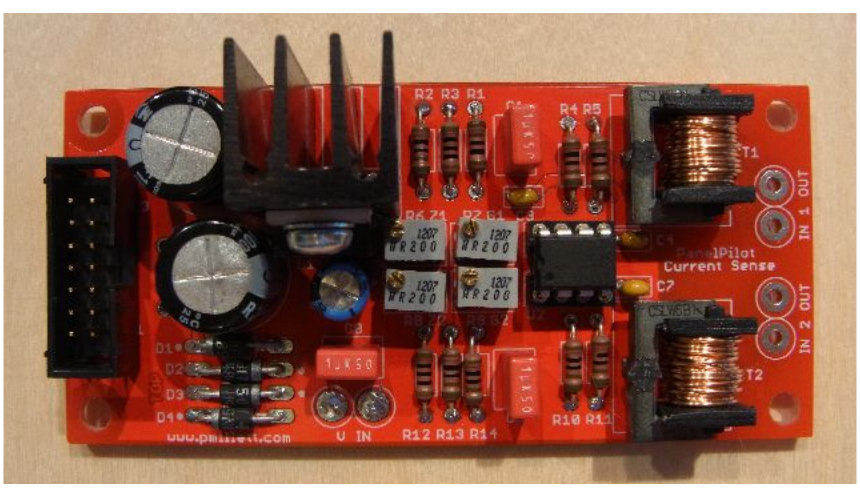


The PCB

To implement all of this, I designed a PCB (are you surprised?) to implement 2 channels of isolated current sensing plus the power supply for this and the PanelPilot meter. The PCB connects to the meter with a 14-pin ribbon cable.

Here's what the bare and assembled PCB looks like:

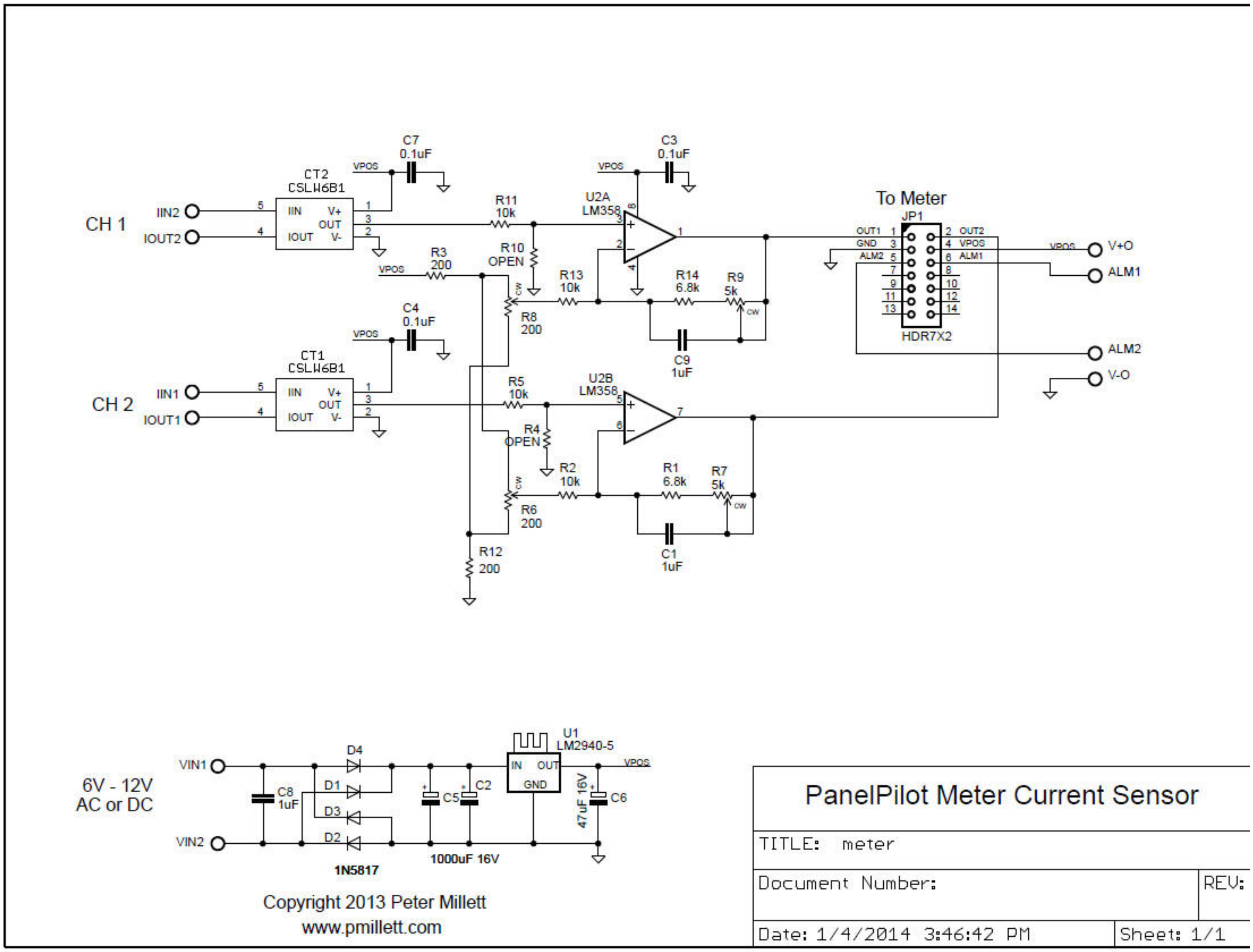


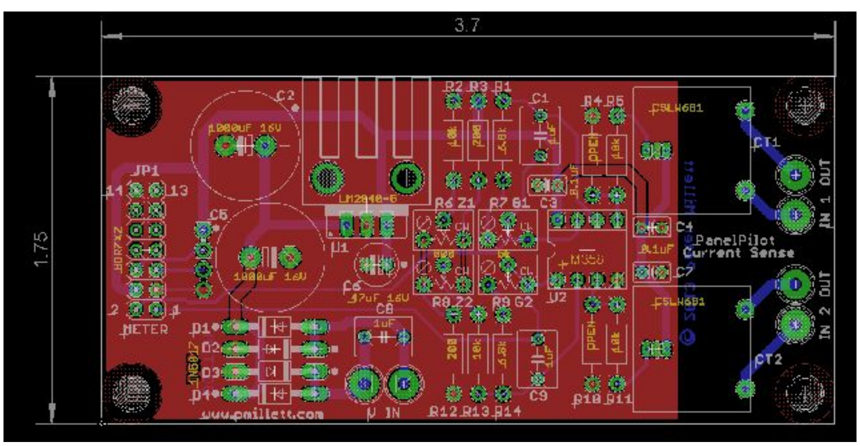


(Don't follow this picture to assemble the PCB - I changed some values. Refer to the schematic and BOM below).

You can find the PCBs on eBay by clicking here.

Here's the schematic (or download a PDF version), and a screen shot of the PCB:





All parts can be gotten from Mouser. Here's the BOM in PDF or XLS format.

Programming

OK, so you build the board... then what?

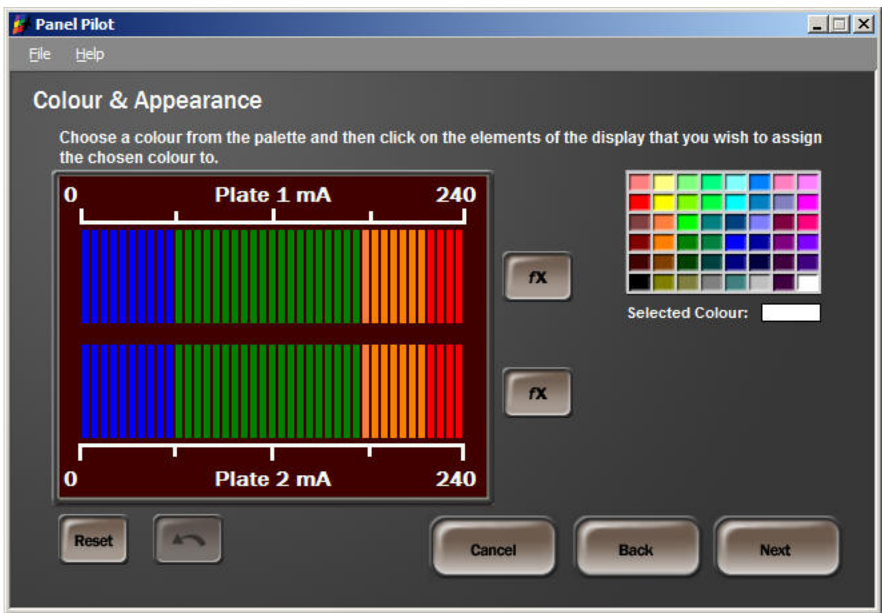
Before this thing is useful, you need to create the setup for the meter on a PC. This is done using the free PanelPilot software. You then need to download your meter programming into the meter, using a USB cable connection from the PC to the meter. The software is pretty self-explanatory, and the PanelPilot website should give you enough info to do this.

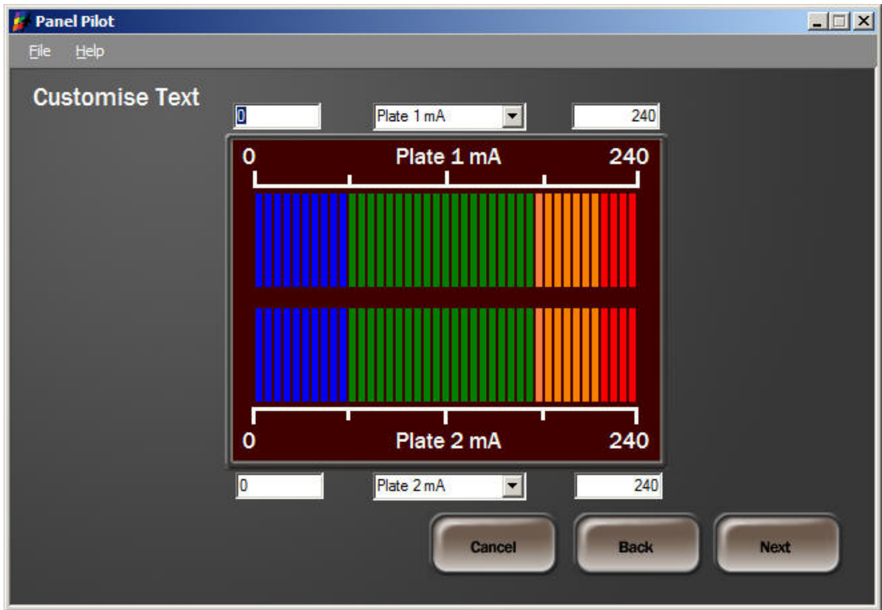
If you are using my PCB as designed above (same opamp gain and current sensors), you need to program the "zero" location to be an input voltage of 2.5V. The "full scale" position is calculated as 2.5V + (2 * FS_A), where FS_A is the full scale current in amps. In my example, full scale is 240mA, so this gives you 2.5V + (2 *

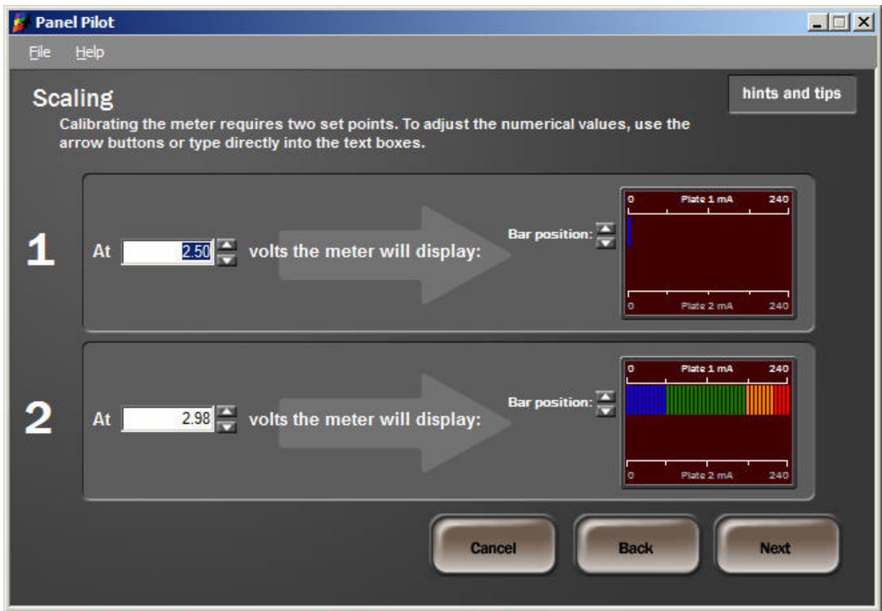
0.24A) = 2.98V.

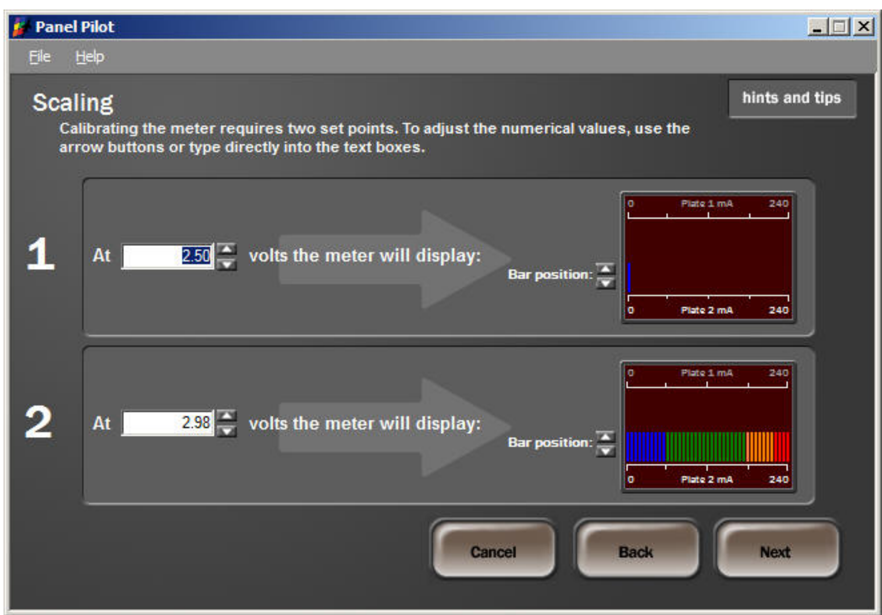
To get you started, here is my programming file (ZIPped .cfg file). you can load this into the PanelPilot software and look at it, and modify it as you wish.

Just in case you get confused, here are screenshots step-by-step for my configuration:




Panel Pilot
File Help
Customise Text
0
Plate 1 mA
240
0 Plate 1 mA 240
0 Plate 2 mA 240
0
Plate 2 mA
240
Cancel
Back
Next


Panel Pilot
File Help
Scaling
hints and tips
Calibrating the meter requires two set points. To adjust the numerical values, use the arrow buttons or type directly into the text boxes.
1 At 2.50 volts the meter will display:
Bar position:
2 At 2.98 volts the meter will display:
Bar position:
Cancel
Back
Next


Panel Pilot
File Help
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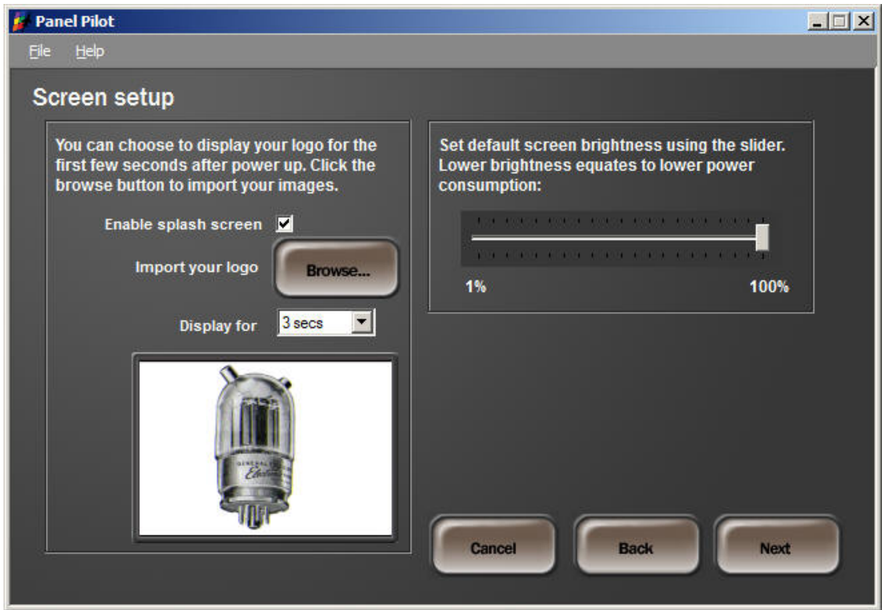
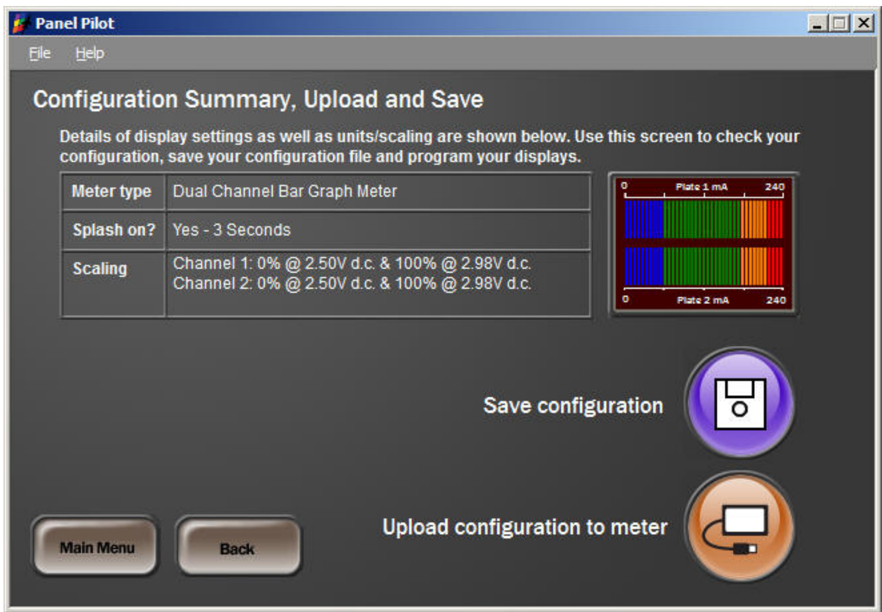
Bar position:
Cancel
Back
Next





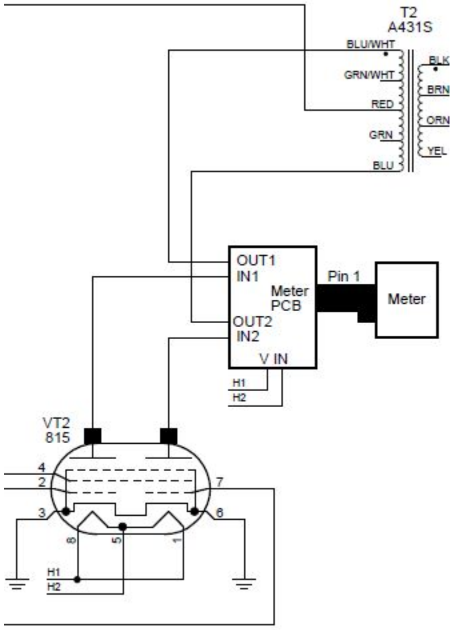
Connections

The current to be measured is provided to the pads labeled (arbitrarily) "IN" and "OUT", one each for each channel. It turned out that the "OUT" side is positive... so if you're sensing plate current, connect "IN" to the plate, and "OUT" to the output transformer. If in the cathode circuit, connect "IN" to ground (or cathode bias) and "OUT" to the cathode.

You need to supply power to the PCB. I power it with 6.3VAC filament power used elsewhere in the amp. You can provide anything from 6V up to ~15V, AC or DC, to the board. It's OK if it has some DC bias on it, since the whole thing is isolated from the rest of the world, so if your filament supply is biased up a bit, no problem.

Connect the PCB to the meter with a ribbon cable, observing the pin 1 location!

Here's an example of the connections to the tube (in this case in the plate leads of an 815):



Calibration

Once you have the PCB assembled, it needs to be calibrated. This is easiest to do outside the amp on a bench, though one could do it in the amp if you had to.

To calibrate the circuit, you need a known current. If you have a bench supply with a current limit, you can just short the output and adjust the current to whatever your full-scale meter current is going to be. If not, you can use a battery and a resistor. Measure the current using a DMM in series. So you form a loop of battery - resistor - DMM - current sensor PCB. Use a resistor that gets you close but not over the full scale reading you want on the meter. For example, for 100mA full scale, you could use a 1.5V battery and a 15 ohm resistor to get a 100mA current. But check it with a DMM - the battery voltage may not be exactly what you think it is!

Apply power to the PCB (6V-12V AC or DC), with nothing connected to the current sense inputs. The meter will power up, display the splash screen (if so programmed), then your meter face. Adjust the "Zero" pots (R6 and R8) until you have a few bars showing (or the meter is just above zero), then turn it until the meter just hits the zero point. Repeat for the other channel, then repeat again (there is some slight interaction between channels).

Alternatively, you can use a DMM to set the output voltage (pins 1 and 2 to the meter) to the meter to exactly 2.50 volts.

Next, apply the full-scale current to the inputs. Note if you want you can connect them in series and set them at the same time. Adjust the FS pots (R7 and R9) to get a full-scale meter reading.

You then should go back and repeat the zero settings, and the FS settings, one more time. Then it is ready for use. Happy metering!

Advanced Topics

If you want to sense very large or very small current, you may want to use a different current sensor. The CSLW series has devices designed for between 200mA and 40A full scale.

You can change the gain of the opamp circuit by changing the feedback resistors and gain pots, R1/R14 and R7/R9. Keep in mind the limitations of the opamp used - if you want to drive very close to 5V, you need a true rail-to-rail opamp.

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Double-Sided Microstrip Circular Antenna Array for WLAN/WiMAX Applications

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ABSTRACT

The design, fabrication, and characterization of the microstrip circular antenna arrays were presented. The proposed antennas were designed for single band at 2.45 GHz and dual bands at 3.3 - 3.6 and 5.0 - 6.0 GHz to support WLAN/WiMAX applications. The proposed single and dual band antennas showed omnidirectional radiation pattern with the gain values of 3.5 dBi at 2.45 GHz, 4.0 dBi at 3.45 GHz, and 3.3 dBi at 5.5 GHz. The dual band antenna array was placed on both top and bottom layers to obtain the desired antenna characteristics. The proposed double-sided dual band antenna provides omnidirectional radiation pattern with high gain.

Keywords: Antenna Arrays; Circular Patch; Dual Band; Single Band; Omnidirectional; WLAN/WiMAX Applications; UWB

1. Introduction

Ultra-wideband (UWB: 3.1 to 10.6 GHz) frequency spectrum has been approved by the US Federal Communications Commission (FCC) for unlicensed short range wireless communications since 2002. In this frequency range, wireless local-area network (WLAN) IEEE802.11a and HIPERLAN/2 WLAN operates in 5.0 - 6.0 GHz band. In some European and Asian countries, world interoperability for microwave access (WiMAX) service is provided in the frequency range of 3.3 - 3.6 GHz [1-4]. To support the WLAN/WiMAX application, antenna arrays that provide omnidirectional radiation pattern are required. To respond to this need, recent antenna design efforts were focused on omnidirectional antennas with high gain and no sidelobes [5-8]. Rectangular arrays are common type used for antenna arrays. Studies on dual band antennas employing rectangular arrays were reported [9-12]. Compared to rectangular patch antenna arrays, there are limited numbers of studies performed on circular patch antenna arrays due to difficulties in fabrication [13]. Advantages of circular antenna array include high gain and narrow beam width [13].

In this paper, a new microstrip circular antenna arrays were designed, fabricated, and characterized to provide omnidirectional radiation pattern for WLAN/WiMAX applications. Two antenna arrays were designed—one for single band at 2.45 GHz and the other for dual bands at 3.3 - 3.6 GHz and 5.0 - 6.0 GHz. For single band operation, circular patch array was placed on the top layer of the microtrip and a small rectangular patch was placed on the bottom layer for ground connection. For dual band operation, similar circular patch array was placed on both top and bottom layers of the microstrip with larger rectangular patch placed on the bottom layer. Both single band (single sided) and dual band (double-sided) microstrip antenna arrays provided desirable antenna characteristics for the intended application.

2. Design and Simulation

2.1. Single-Band Antenna at 2.45 GHz

The configuration of the proposed single band antenna at 2.45 GHz is shown in **Figure 1**. It consists of six circular patches which are placed only on the top layer. The small rectangular patch is placed on the bottom layer for ground connection.

The directivity for the circular patch antenna is

$$D_0 = \frac{(k_0 a_e)^2}{120 G_{\mathrm{rad}}} \quad (1)$$

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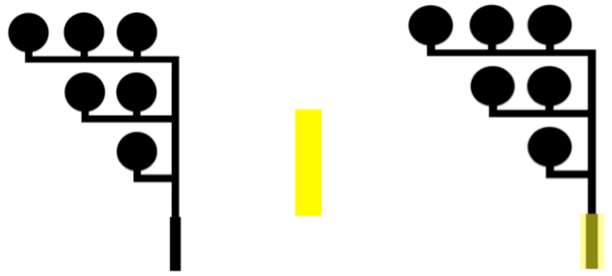


(a) (b) (c)

Figure 1. Configuration of the proposed antenna for single band at 2.45 GHz: (a) Top layer; (b) Bottom layer; (c) Top and bottom layers overlaid.

$$k_0 = \frac{2\pi}{\lambda_0} \tag{2}$$

$$a_e = a\left\{1+\frac{2h}{\pi a \epsilon_r}\left[\ln\left(\frac{\pi a}{2h}\right)+1.7726\right]\right\}^{1/2} \tag{3}$$

$$G_{\text{rad}} = \frac{(k_0 a_e)^2}{480}\int_0^{\pi/2}\left[J_{02}'^2+\cos^2\theta J_{02}^2\right]\sin\theta \mathrm{d}\theta \tag{4}$$

$$J_{02}' = J_0(k_0 a_e \sin\theta) - J_2(k_0 a_e \sin\theta) \tag{5}$$

$$J_{02} = J_0(k_0 a_e \sin\theta) + J_2(k_0 a_e \sin\theta) \tag{6}$$

where a_e is the effective radius, a is the actual radius, ϵ_r is the relative permittivity of the microstrip dielectric substrate, h is the height of the microstrip substrate, and J_0 and J_2 are Bessel functions.

The gain of the antenna was calculated using

$$\text{Gain} = \text{Antenna Efficiency} \times \text{Directivity}(D_0) \tag{7}$$

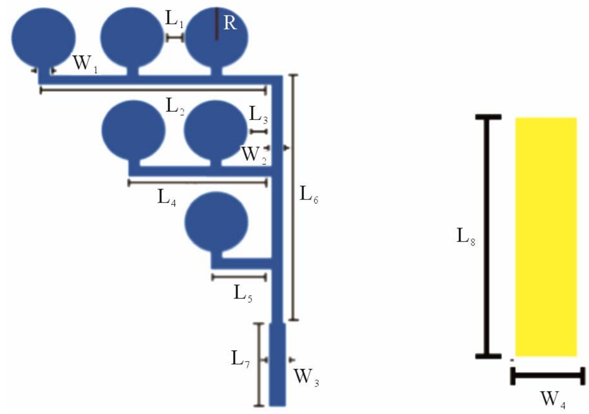
$$\text{Antenna Efficiency} = \frac{\text{Total Efficiency}}{\text{Reflection Efficiency}} \tag{8}$$

The variable corresponding to each dimensions and values for the dimensions of the proposed antenna are shown in **Figure 2** and **Table 1**, respectively. Here, *L*, *W*, and *R* represent the length, the width, and the radius of the circular patch, respectively.

The gain of the proposed antenna shown in **Figure 1** was calculated using (1) - (8) and the dimensions were optimized using ADS [14] which resulted in gain of 3.5 dBi at 2.45 GHz.

2.2. Dual-Band Antenna at 3.3 - 3.6 and 5.0 - 6.0 GHz

The configuration for the doubled-sided microstrip dual band antenna is shown in **Figure 3**. The proposed microstrip antenna has circular arrays both on the top and bottom layers. It consists of three circular patched on each layer.

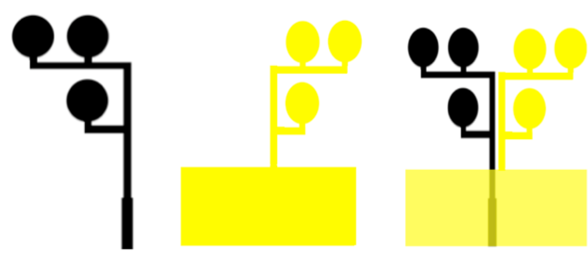


(a) (b)

Figure 2. Variables corresponding to each dimension of the proposed single band antenna: (a) Top layer; (b) Bottom layer.

Table 1. Dimensions for the proposed single band antenna at 2.4 GHz.

Variable	Value (mm)
L_1	1.15
L_2	28.9
L_3	1.13
L_4	17.6
L_5	6.60
L_6	35.3
L_7	18.4
L_8	18.4
W_1	1.02
W_2	1.52
W_3	3.30
W_4	6.86
$\boldsymbol{R}$	5.10



(a) (b) (c)

Figure 3. Configuration of the proposed antenna for dual band at 3.3 - 3.6 and 5.0 - 6.0 GHz: (a) Top layer; (b) Bottom layer; (c) Top and bottom layers overlaid.

The configuration in **Figure 3(a)** is similar to the top layer of the single band antenna as shown in **Figure 1(a)** but with less circular patches. However, the bottom layer in **Figure 3(b)** is different compared to the bottom layer of the single band antenna shown in **Figure 1(b)**. The double-side nature of the antenna provides dual band characteristics. Identical equations were used for the single band antenna were employed in the design process. The variable corresponding to each dimensions and the dimensions for the proposed dual band antenna are shown in **Figure 4** and **Table 2**, respectively.

Simulation was performed using ADS for the configuration shown in **Figure 3(c)**. The simulated gains of the proposed dual band antenna were 4.0 dBi at 3.45 GHz and 3.3 dBi at 5.5 GHz. The double-sided configuration of the antenna provided higher gain compared to the singled-sided antenna.

3. Measurement Results and Discussions

3.1. Single-Band Atnenna at 2.45 GHz

The antennas were fabricated using LPKF Protomat [15] on FR-4 material with height of 1.524 mm. The photos of the fabricated single band antenna are shown in **Figure 5** which has a size of 6.7 × 4.4 (in cm).

Figure 6 shows the comparison between the simulated and the measured S_{11} results.

The measured operating frequency is close to 2.45 GHz with S_{11} value below −15 dB. The 3 dB bandwidth at 2.45 GHz was approximately 18%. The measurement and simulation are in fairly good agreement, and the differences are due to microstrip loss and fabrication errors.

Figure 7 shows the comparison between the simulated and measured radiation pattern in xy-plane at 2.45 GHz which is close to omnidirectional pattern.

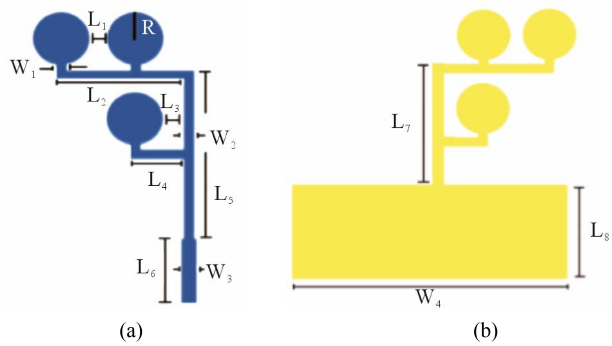


Figure 4. Variables corresponding to each dimension of the proposed dual-band antenna: (a) Top layer; (b) Bottom layer.

Table 2. Dimensions for the proposed dual band antenna at 3.3 - 3.6 and 5.0 - 6.0 GHz.

Variable	Value (mm)
L_1	1.20
L_2	17.8
L_3	1.08
L_4	6.60
L_5	29.3
L_6	10.0
L_7	21.6
L_8	17.8
W_1	1.02
W_2	1.52
W_3	2.54
W_4	49.1
R	5.21

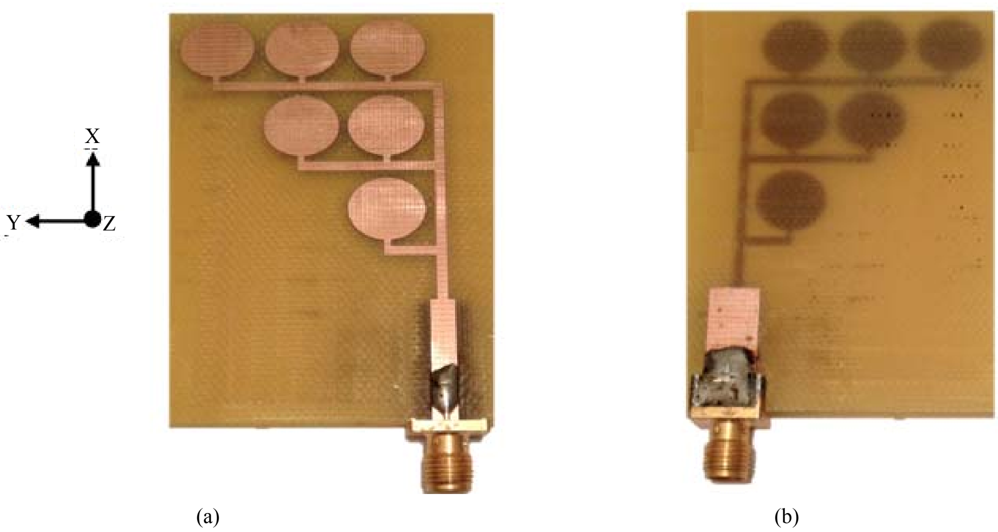


Figure 5. Photo of the fabricated single-band antenna: (a) Top layer; (b) Bottom layer.

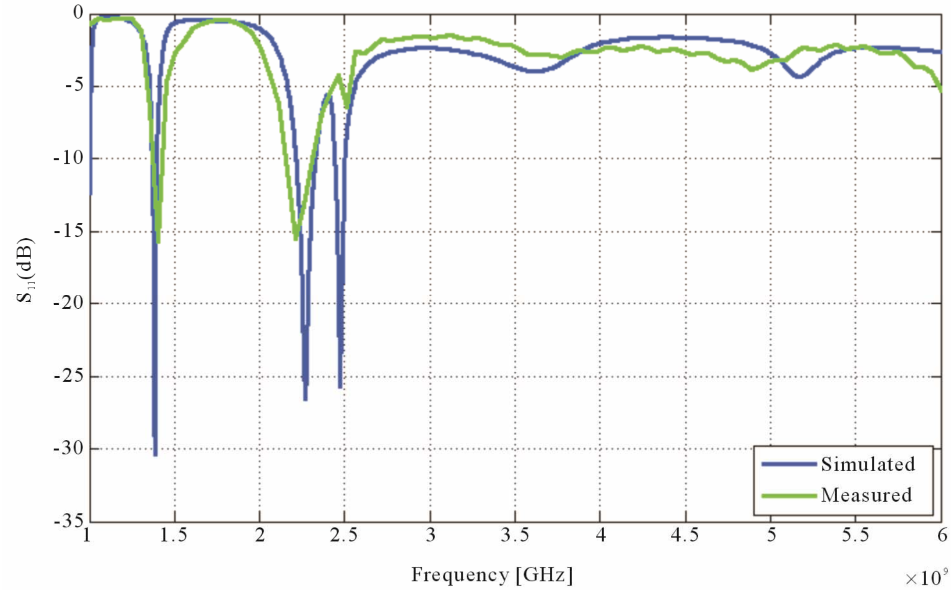


Figure 6. Simulated and measured return loss for the proposed single-band antenna.

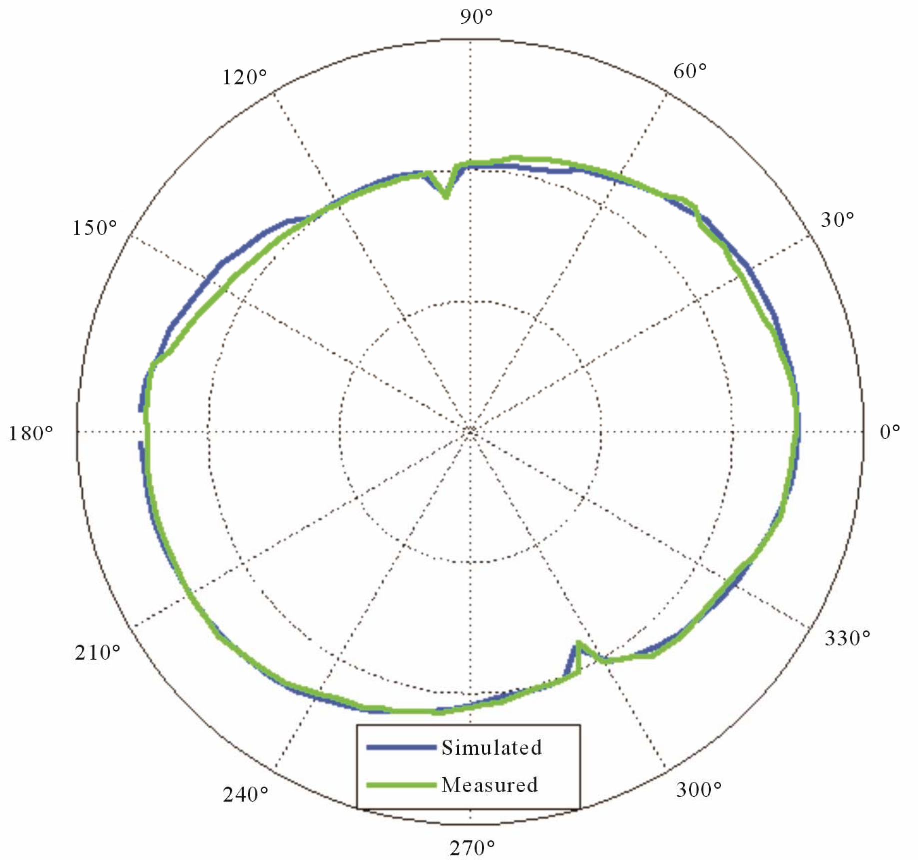
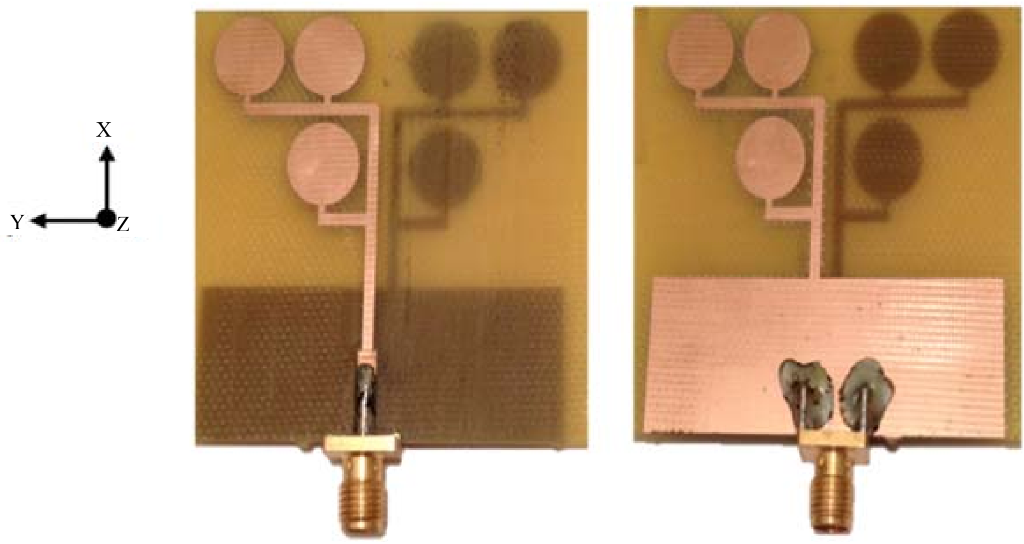


Figure 7. Simulated and measured radiation pattern in xy-plane (coordinate system shown in Figure 5) at 2.45 GHz.

3.2. Dual-Band Antenna at 3.3 - 3.6 and 5.0 - 6.0 GHz

The antennas were fabricated using LPKF Protomat [15] on double-sided FR-4 materials. The photos of the fabricated dual band antenna are shown in **Figure 8** which has a size of 6.6 × 5.2 (in cm).

Figure 9 shows the comparison between the simulated



(a) (b)

Figure 8. Photo of the fabricated dual-band antenna: (a) Top layer; (b) Bottom layer.

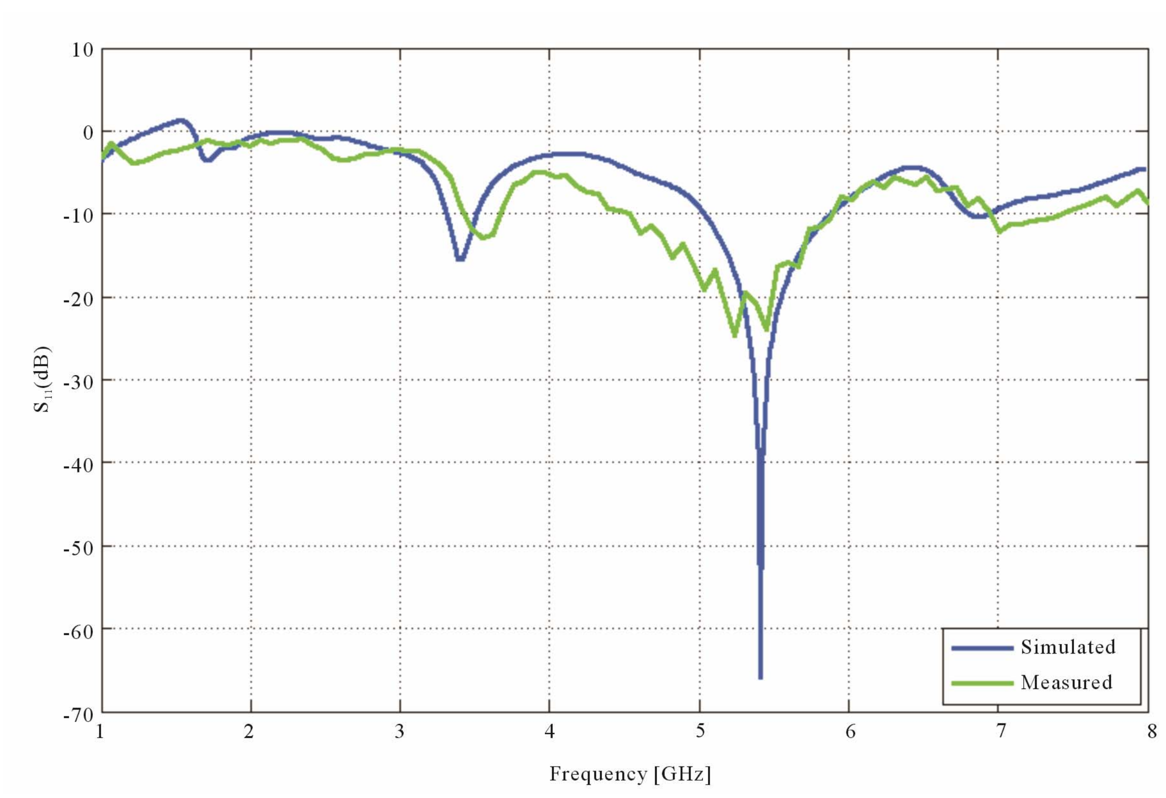


Figure 9. Simulated and measured return loss for the dual band antenna.

and the measured S_{11} results.

The measured S_{11} shows dual band near the designed bands with S_{11} values below −10 dB for both bands. The simulated and measured results give fairly good agreement, and the differences are due to board loss and fabrication errors.

Figure 10 shows the comparison between the simulated and measured radiation pattern in xy-plane at 3.45 and 5.5 GHz which is close to omnidirectional pattern.

4. Conclusion

A microstrip circular antenna arrays were presented for single band at 2.45 GHz and dual bands at 3.3 - 3.6 and

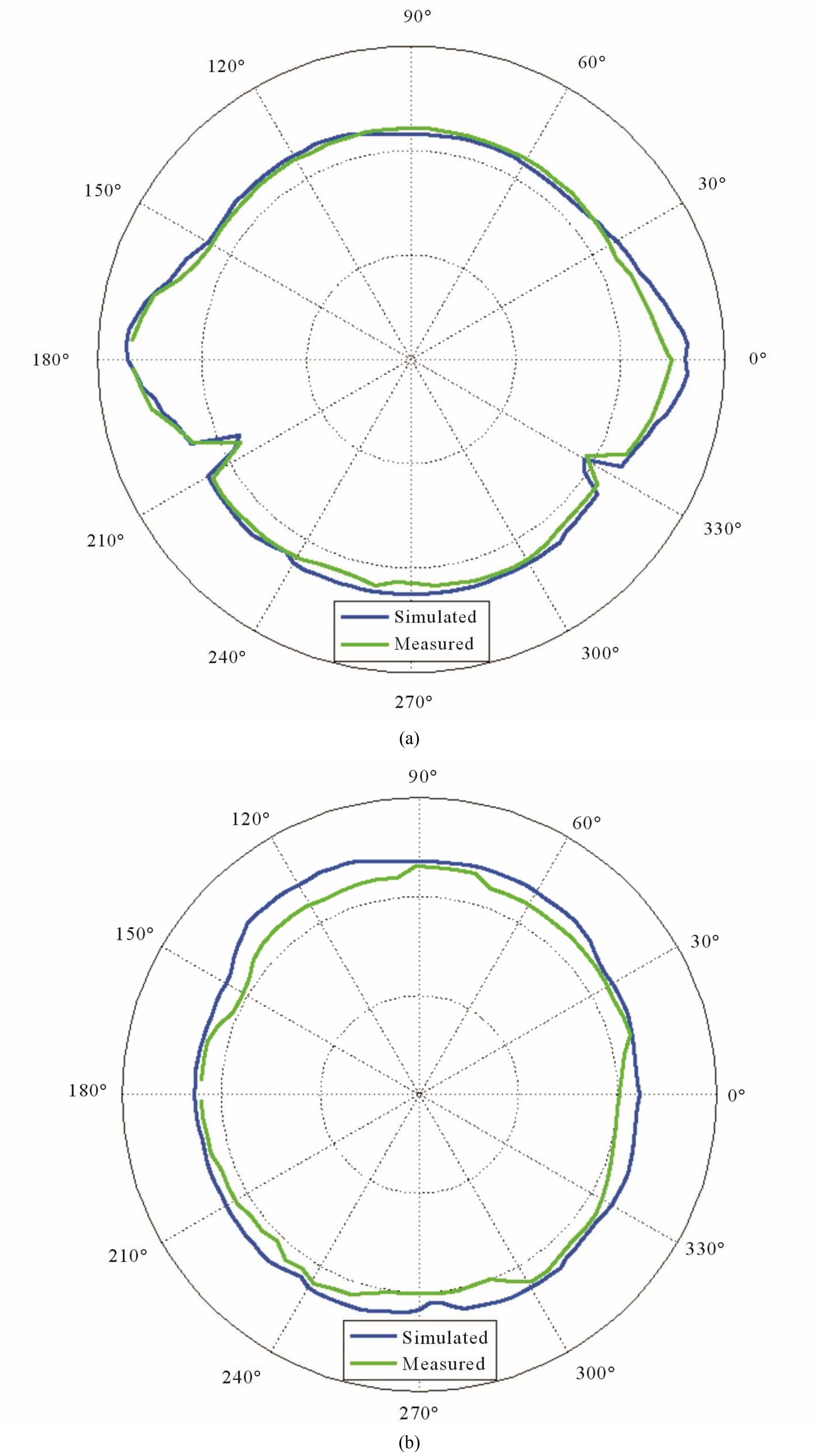


Figure 10. Simulated and measured radiation pattern in xy-plane (coordinate system shown in Figure 8) at (a) 3.45 GHz and (b) 5.5 GHz.

5.0 - 6.0 GHz for WLAN/WiMAX applications. Both antennas were designed with ADS, fabricated on a FR-4 microstrip material, and characterized. Both single band (single sided) and dual band (double-sided) antenna arrays provided omnidirectional pattern with desired gain.

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Design and fabrication of 12 GHZ microstrip directional coupler for RF/microwave application

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Zairi Rizman
Universiti Teknologi MARA

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DESIGN AND FABRICATION OF 12 GHZ MICROSTRIP DIRECTIONAL COUPLER FOR RF/MICROWAVE APPLICATION

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Abstract

Microstrip coupled line is parallel coupled transmission lines formed by coupling two conducting strips (resonator) with the same width together at a certain distance. This paper presents the design of microstrip directional coupler without the prior knowledge of the physical geometry. A general configuration directional coupler will be determined by creating a layout in the Agilent Advanced Design System (ADS) and momentum. In order to perform simulation, a substrate as well as metallization and mesh should be defined. Hence, the required s-parameter response of the coupler could be obtained. The design will then fabricate on top of RT Duroid 6010 substrate, and finally undergo measuring through Vector Network Analyzer (VNA) to evaluate their S-parameter characteristics. Simulated results show insertion loss, isolation, coupling (10.82 dB), and return loss were within the acceptable limits. Directivity of better than 23 dB was achieved in the simulated response. The coupling (9.99 dB) of fabricated circuit shows a good agreement with the required specification (10 dB), but the directivity 10.61 dB is quite low in practice. The reason for the discrepancy could, however, due to discontinuities, measuring errors, and fabrication error. However, coupling values show a good agreement between the simulation and measured results.

Keywords: Microstrip, Coupled line, Directional coupler, Coupling, Directivity.

1. Introduction

The microstrip is a mixed dielectric system or inhomogeneous, having solid dielectric below, and air above as demonstrated in Fig. 1. These mixed systems can only support multi-modal propagation behaviour at any particular frequency,

Nomenclatures

C	Coupling, dB
dB	Decibel
E	Electric field, V/m
F	Centre frequency, GHz
GHz	Giga hertz
H	Substrate thickness, mm
l/L	Length, mm
S	Scattering parameter
s	Spacing, mm
S_{11}	Return loss, dB
S_{21}	Coupled signal, dB
S_{31}	Isolation , dB
S_{41}	Transmitted signal (transmission)
W	Width, mm
Z_o	Output impedance, Ω
Z_{oe}	Even-mode output impedance, Ω
Z_{oo}	Odd-mode output impedance, Ω

Greek Symbols

β_e	Even-mode phase constant
β_o	Odd-mode phase constant
ε_r	Substrate permittivity, As/Vm
Γ_e	Even-mode reflection coefficient
Γ_o	Odd-mode reflection coefficient

Abbreviations

ADS	Advanced Design System
MCLIN	Microstrip Coupled Line
MLIN	Microstrip Line
PCB	Printed Circuit Board
SMA	SubMiniature version A
TEM	Transverse Electro-magnetic
VNA	Vector Network Analyzer
VSWR	Voltage Standing Wave Ratio

due to the discontinuity in the electric structure. In other words, the structure does not support pure TEM wave.

The field patterns in a microstrip are such that the bulk of the energy is transmitted in a TEM like mode, and this approximation is often made, so propagation in microstrip is often referred as ‘quasi-TEM’ [1]. TEM stands for Transverse Electro-magnetic, and means that the electric and magnetic fields are entirely directed in a plane transverse to the direction of propagation.

Parallel coupled line couplers are widely used for many wireless and microwave applications because they can be easily implemented and incorporated with other circuits. Microstrip coupled line is parallel coupled transmission lines formed by coupling two conducting strips (resonator) with the same width together at a certain distance, as depicted in Fig. 2 [2]. The odd- and even-mode

characteristic impedance can be analyzed by individual even-mode and odd-mode circuits. It should be noticed that, phase velocity of even-mode is greater than odd-mode phase velocity due to more of the odd-mode electric fields (E) travels in the air. Then, the wavelength of individual mode is absolutely different from each other [3].

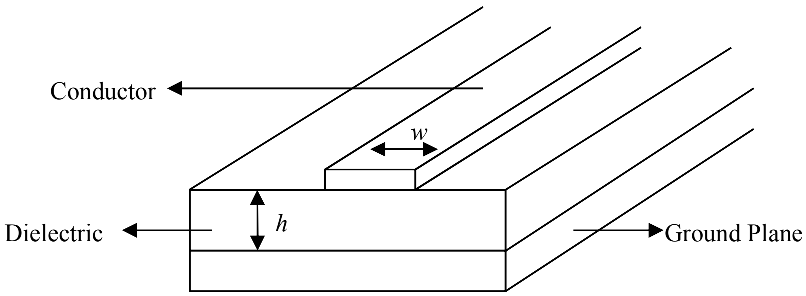

Fig. 1. Microstrip line.

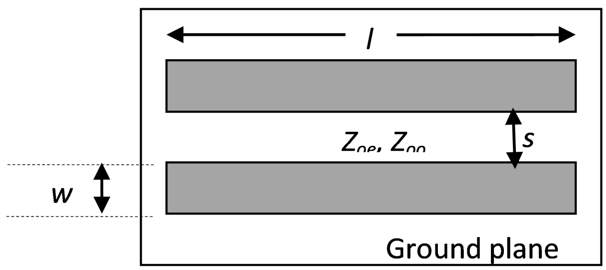

Fig. 2. Top view of two port parallel coupled line.

The analysis of a coupled transmission line can be described by S-parameter in order to observe the coupling characteristics. As shown in Fig. 3, all ports are labelled, and are all terminated in the system characteristic impedance Z_o. In this case, it is assumed that the two lines have the same characteristic impedance, and so the whole structure is symmetrical. If port 1 is the input port, then the characteristics can be determined by derivation based on the four ports, as shown in Eq. (1).

$$S_{11} = \frac{b_1}{a_1},\ S_{21} = \frac{b_2}{a_1},\ S_{31} = \frac{b_3}{a_1},\ S_{41} = \frac{b_4}{a_1} \tag{1}$$

where S_{11} is the return loss, S_{21} is the coupled signal, S_{31} is the isolation and S_{41} is the transmitted signal (transmission). Each of even-mode and odd-mode has associated characteristic impedance and phase constant, Z_{oe} and β_e for the even mode and Z_{oo} and β_o for the odd mode. The derivations for the above four parameters are complex and mentioned in many published sources [4-15]. The final definitions are expressed as Eq. (2).

$$S_{11} = \frac{\Gamma_e + \Gamma_o}{2}, S_{21} = \frac{\Gamma_e - \Gamma_o}{2}, S_{31} = \frac{T_e - T_o}{2}, \; S_{41} = \frac{T_e + T_o}{2} \tag{2}$$

where Γ_e is the even-mode reflection coefficient, Γ_o is the odd-mode reflection coefficient, T_e is the even-mode transmission coefficient and T_o is the odd-mode transmission coefficient.

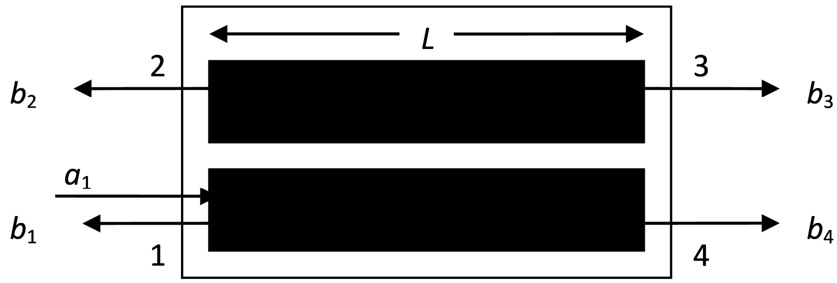

Fig. 3. Asymmetrically excited pair of coupled line.

For the ideal coupler, the value of phase constant of each odd and even mode are similar and $S_{11} = S_{31} = 0$. The power will split between ports 2 and 4 with a 90^o phase shift between the signals. This is called a quadrature hybrid coupler. Due to symmetry, power input into port 4 splits between ports 1 and 3 with 90^o phase shift, input to port 3 splits between ports 2 and 4, etc [16]. However, when implementing the directional coupler in microstrip transmission line, the effect of phase velocity difference between even and odd mode exhibits poor directivity. The directivity is a measure how well coupler can isolate two signals. Higher directivity results in better measurement accuracy. As a result, it is the most designed parameter for accurate measurement systems. However, it is a great challenge to preserve directivity, amount of desired coupling level, low Voltage Standing Wave Ratio (VSWR) [17] and insertion loss for wideband microwave applications [18].

In this paper, a simple design procedure is used with model approximation formulation. It comprises a complete design of symmetrical two-line microstrip directional coupler. However, the physical length of the coupler is initially unknown. The only information that can be obtained is port impedances, required coupling level, and operational frequency at the initial stage of the design. Thus, this requires several iterations to finalize the design.

2. Design of Directional Coupler

The geometry of a parallel coupled line directional coupler is as shown in Fig. 1. As it is outlined in the introduction section, we assume that port impedance Z_o, coupling and the operational frequency are known parameters at beginning of the design. The initial specifications for the designed directional coupler are shown in Table 1. Based on the known parameters, the proposed procedure has the following steps.

Table 1. Directional coupler designed specifications.

Parameter	Value
Coupling, *C*	10 dB
Centre frequency, *f*	12 GHz
Substrate permittivity, ε_r (RT Duroid 6010LM)	10.2
Substrate thickness, *h*	0.635 mm
Copper thickness, *t*	17 µm
Tan δ	0.0012 at 10 GHz

2.1. Step 1: Find even and odd mode impedances

The equations used in the design are based on transmission line model approximation. The even and odd mode impedances, Z_{oe} and Z_{oo}, of the microstrip coupler can be found as

$$Z_{oo} = Z_o X \sqrt{\frac{1-10^{-C/20}}{1+10^{-C/20}}} \tag{3}$$

$$Z_{oe} = Z_o X \sqrt{\frac{1+10^{-C/20}}{1-10^{-C/20}}} \tag{4}$$

where Z_o is the network characteristic impedance of 50 Ω [19] and C is the forward coupling requirement in decibels. The value of coupling (C) then substitutes into Eqs. (3) and (4), the values of Z_{oe} and Z_{oo} are 69.37 Ω and 36.04 Ω, respectively.

2.2. Step 2: Agilent ADS simulation

All the values and the specifications in Table 1 were included as the data in the Advanced Design System (ADS) electronic software. The software simulated the data and automatically calculated the dimensions of Microstrip Coupled Line (MCLIN) and Microstrip Line (MLIN) by using 'linecalc' tool bar. Table 2 shows the dimensions of MCLIN and MLIN. With these geometric dimensions, the physical structure can be modelled with the inventory of the circuit element provided, as shown in Fig. 4. In order to accomplish a best simulation result as specifications required, several iterations had been done accordingly.

With the Agilent ADS, its schematics diagram layout is closely integrated with momentum layout of the designed circuits. The layout of directional coupler circuit is automatically generated. Any changes of the schematic diagram will be affected in the momentum layout. Figure 5 shows the momentum layout of passive directional coupler.

Table 2. Dimensions of MCLIN and MLIN.

Parameter	MCLIN	MLIN
Width, *w*	0.487239 mm	0.596374 mm
Length, *l*	2.4168 mm	2.33598 mm
Spacing, *s*	0.239712 mm	

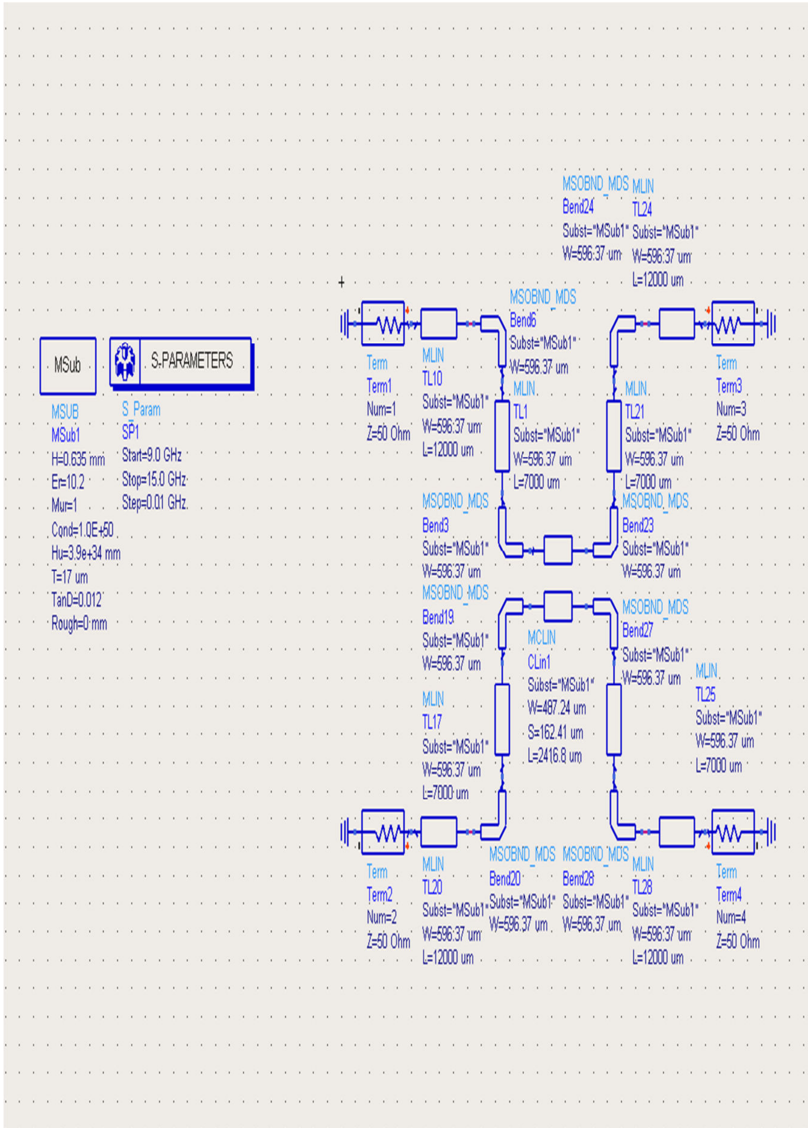

Fig. 4. Schematic diagram of directional coupler.

2.3. Step 3: Directional coupler fabrication

As can be seen, several microstrip corner pads have been added in the schematic diagram to avoid coupling effect between arms and also the distance between arms become wider. Hence, the respective arms can attach or connect to the SubMiniature version A (SMA) connector during fabrication [20]. The layout will be printed and fabricated on top of RT Duroid 6010 material with $\varepsilon_r = 10.2$ and the thickness, $h = 0.632$ mm.

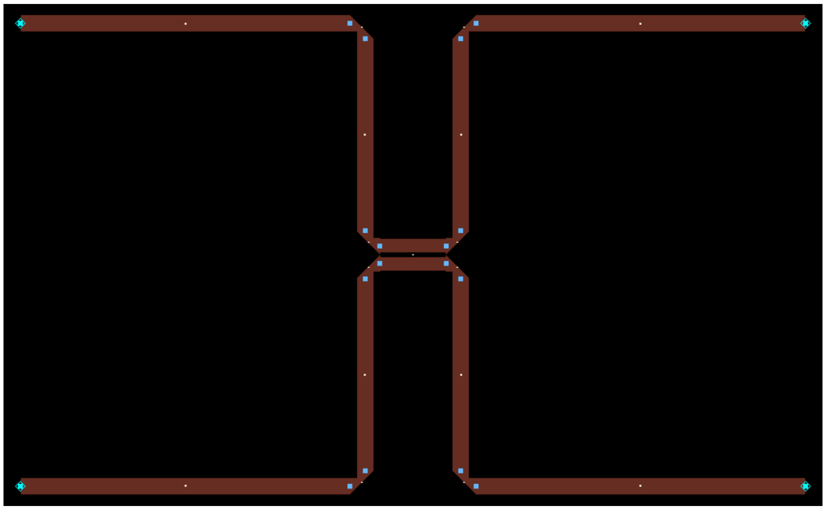

Fig. 5. Momentum layout of directional coupler.

3. Results and Discussion

It is a great challenge to preserve an amount of desired coupling level, high directivity and low insertion loss for microwave applications. The directivity is a measure of how effective the directional coupler is in "directing" the coupled energy into the coupled port, but not into the isolation port. Ideally, directivity is infinite, so the higher the directivity, the better the device is.

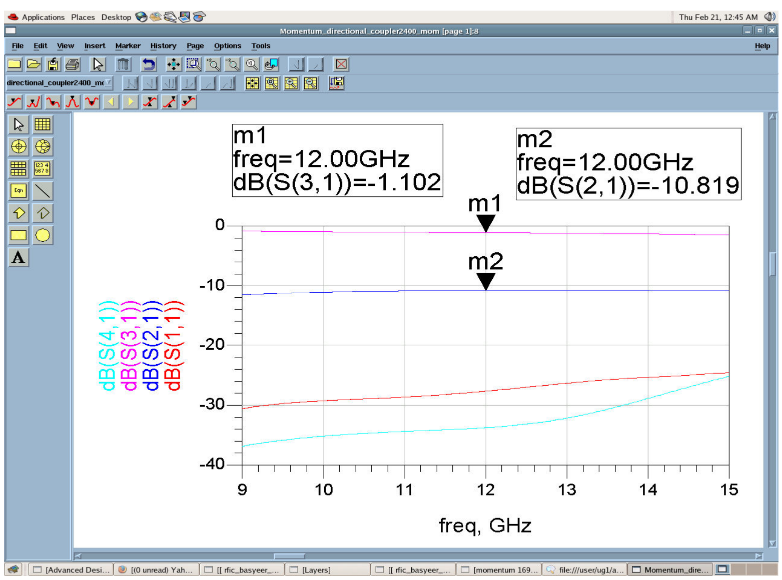

Fig. 6. Simulated result of directional coupler.

As simulated result shown in the Fig. 6, the value of coupling (S_{21}) is 10.819 dB at 12 GHz. It is slightly greater than of the required coupling specification. The differences in coupling factor due to the physical length, width, and spacing between microstrip of the directional coupler circuit computed from simulation process compared with design procedure with accurate formulation. Furthermore, the design procedure only depends on the knowledge of required coupling level, the port impedances that directional coupler will be connected to, and operational frequency [21]. However, all the results such as insertion loss, isolation, coupling and return loss were within the acceptable limits. Directivity of better than 23 dB was achieved in the simulated response. Furthermore, the error of coupling factor of the simulated result compared to required specifications is 8.19% and is considerably small.

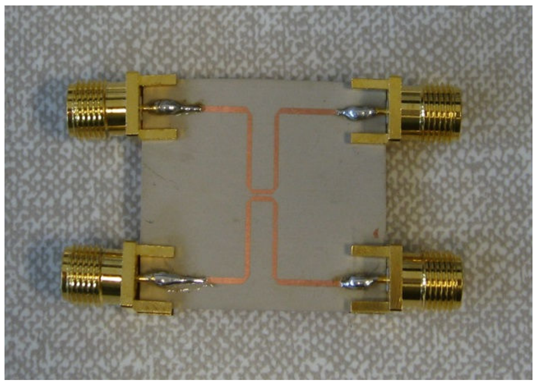

Fig. 7. Directional coupler fabricated circuit.

In order to prove the design, a coupler corresponding to Fig. 5 is fabricated on RT Duroid 6010 substrate as per photograph given in Fig. 7. The fabrication was measured by using Vector Network Analyzer (VNA) [22], as shown in Figs. 8, 9, and 10. Isolation is plotted instead of directivity to give better graphical view and directly be calculated at any point by subtracting coupling factor from it [23]. There is a good agreement between the simulation results and measured one. It can be seen clearly that measured coupling (9.99 dB) shows a better result compared to simulated result and almost fulfil the specification requirement (10 dB). In spite of that, the isolation response (20.6 dB) of measured coupler indicates lower performance compared to the simulated result (about 34 dB). By subtracting the measured result between isolation and coupling, the result exhibits low directivity (10.61 dB) which is not suitable for measurement systems accuracy.

The reason for the discrepancy could, however, due to discontinuities and measuring errors which are not taken into account [24]. Error in fabrication could be another possible source of discrepancies to the measured result. The difficulty encountered in fabrication is to ensure that the thickness of copper conductor exactly at 17 μm according to the simulation done earlier and also as notified in the standard procedure. As the printing carried out, the copper thickness and pattern follow the screens that had been produced earlier.

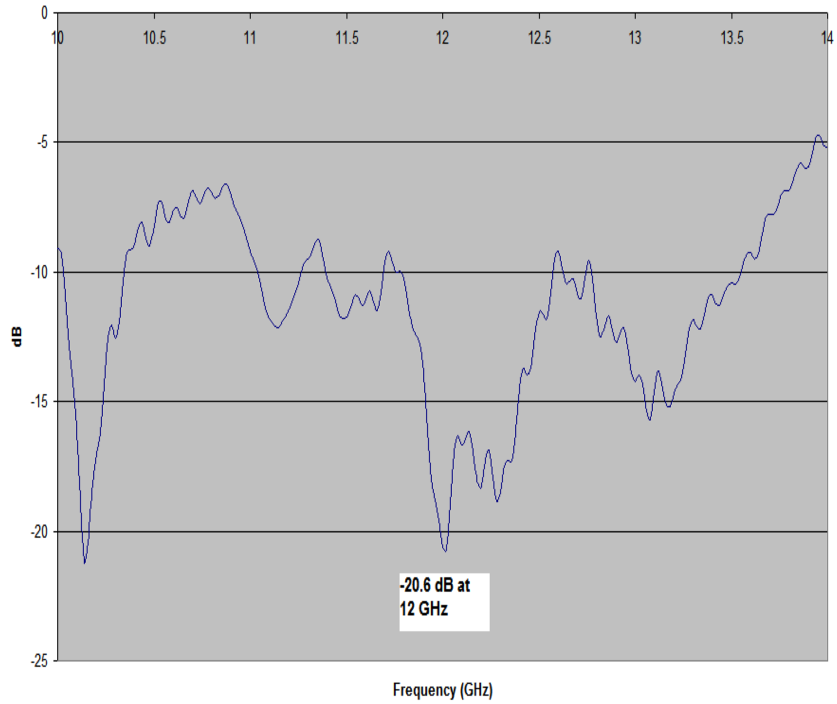

Fig. 8. Isolation result.

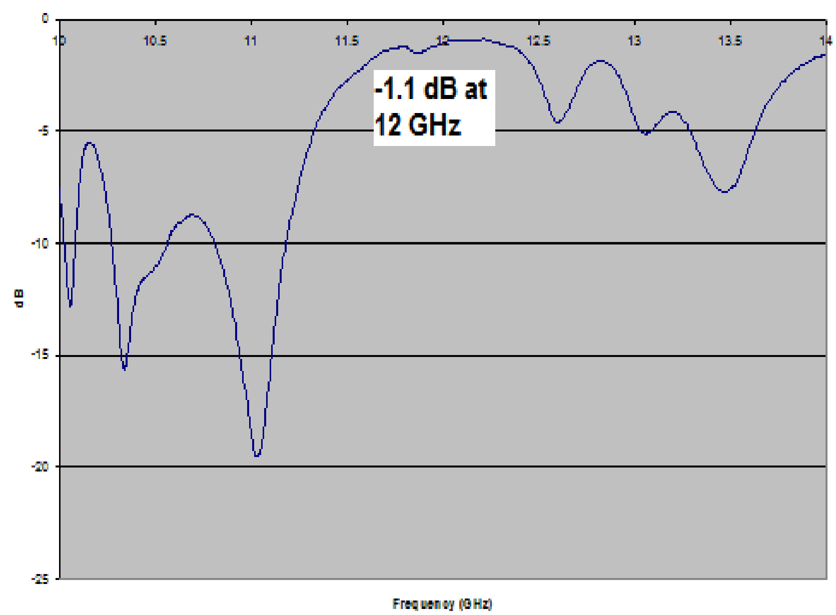

Fig. 9. Insertion loss result.

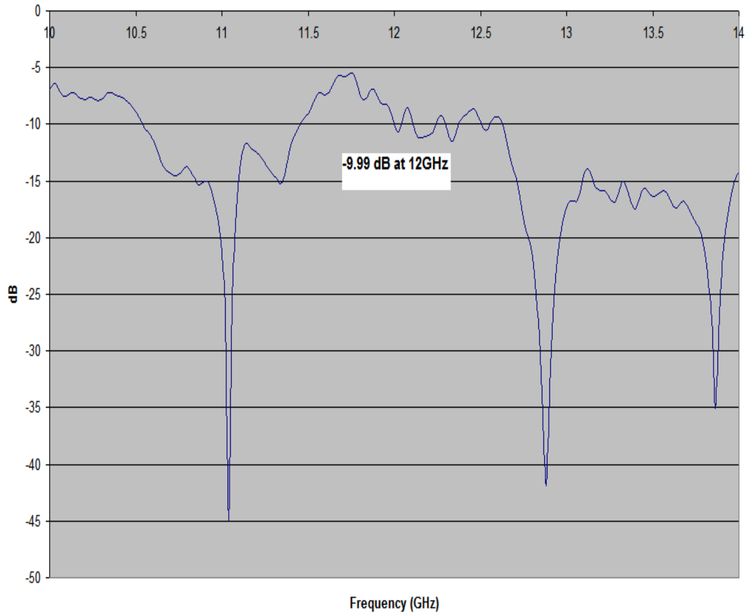

Fig. 10. Coupling result.

4. Conclusions and Recommendations

In this paper, the design of microstrip directional coupler is presented by a simple design procedure. The validity of the design circuit is verified by comparing the simulated and measured responses. The coupling (9.99 dB) of fabricated circuit shows a good agreement with the required specification (10 dB) [25], but the directivity results 10.61 dB which quite low in practice. There is a good agreement regarding coupling factor between the simulation results and measured one. However, the directivity of the measured result was not within acceptable limit compared to the simulation one. The main important parameter in achieving good coupling is the gap of the coupled resonators should be very small. Hence, the coupling gap should be adjusted manually during simulation.

The higher frequency operating is, the smaller the circuit. In that case, the designed 12 GHz dielectric coupler might be influenced by more serious sources of error when fabricated in Printed Circuit Board (PCB) technology. Therefore, thick film technology could be utilized in order to provide better accuracy in circuit fabrication and yield better performance.

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United States Patent [19]

Rogers, Sr.

[11] **4,292,804**

[45] **Oct. 6, 1981**

[54] **METHOD AND APPARATUS FOR OPERATING AN ENGINE ON COMPRESSED GAS**

[76] Inventor: **Leroy K. Rogers, Sr.,** #5 Capistrano Ct., Ft. Myers, Fla. 33908

[21] Appl. No.: **158,303**

[22] Filed: **Jun. 10, 1980**

[51] **Int. Cl.**[3] **F15B 11/06**

[52] **U.S. Cl.** **60/407;** 91/187; 91/275

[58] **Field of Search** 60/407, 412; 91/187, 91/275, 364

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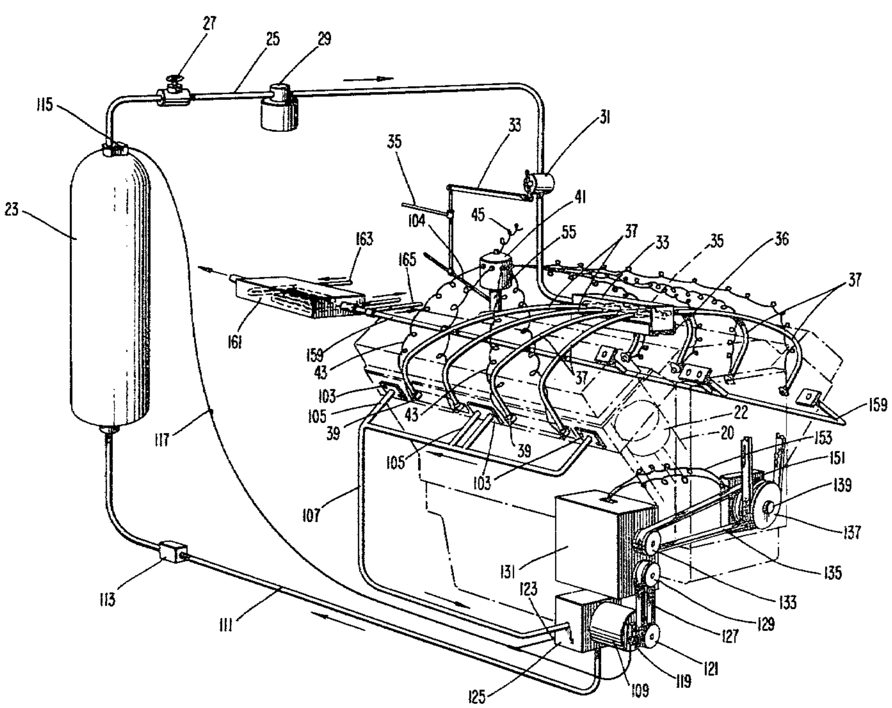
Primary Examiner—Allen M. Ostrager

Attorney, Agent, or Firm—Burns, Doane, Swecker & Mathis

[57] **ABSTRACT**

The present invention relates to a method and apparatus for operating an engine having a cylinder and a piston reciprocable therein on compressed gas. The apparatus comprises a source of compressed gas connected to a distributor which distributes the compressed gas to the cylinder. A valve is provided to selectively admit compressed gas to the cylinder when the piston is in an approximately top dead center position. In one embodiment of the present invention the timing of the opening of the valve is advanced such that the compressed gas is admitted to the cylinder progressively further before the top dead center position of the piston as the speed of the engine increases. In a further embodiment of the present invention a valve actuator is provided which increases the length of time over which the valve remains open to admit compressed gas to the cylinder as the speed of the engine increases. A still further embodiment of the present invention relates to an apparatus for adapting a conventional internal combustion engine for operation on compressed gas.

22 Claims, 8 Drawing Figures



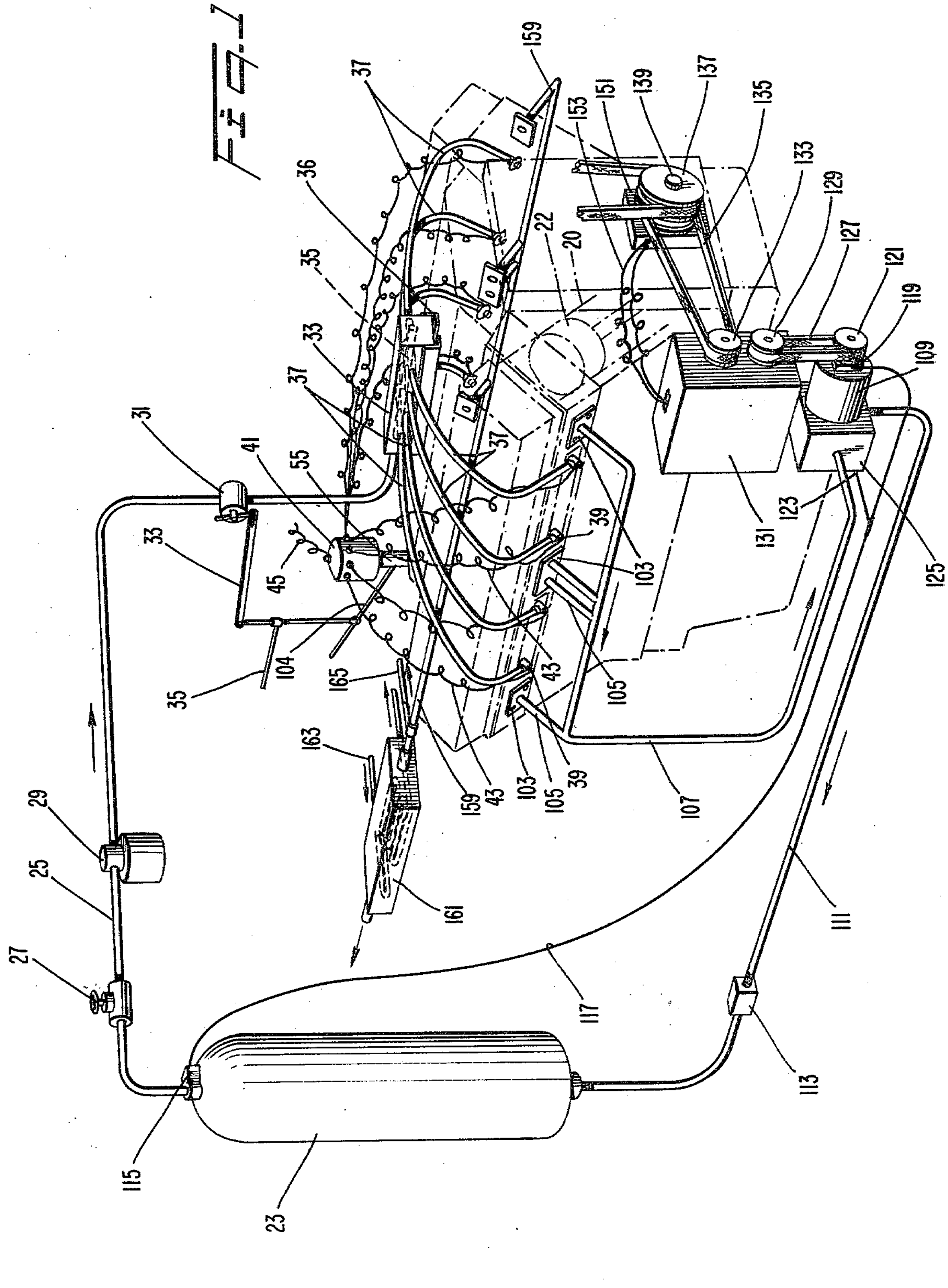


FIG. 1

Fig. 6

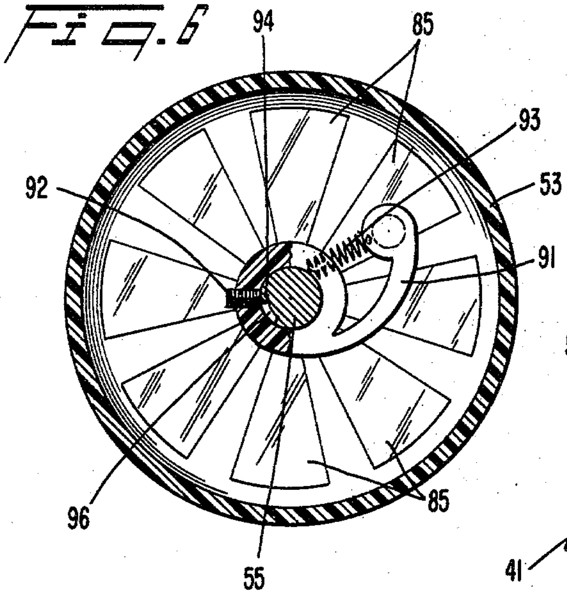
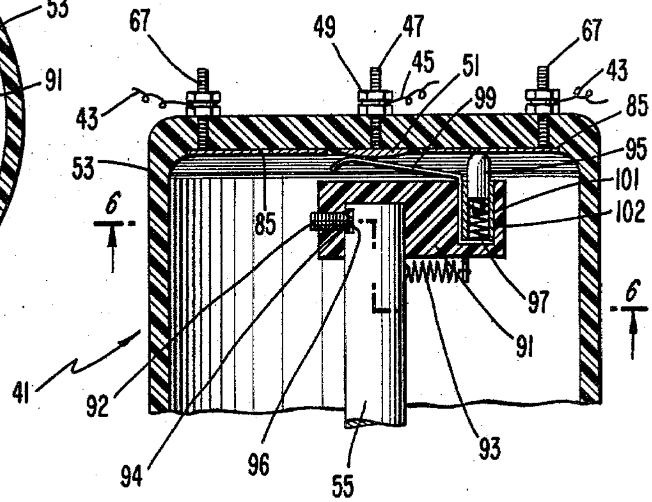


Fig. 7



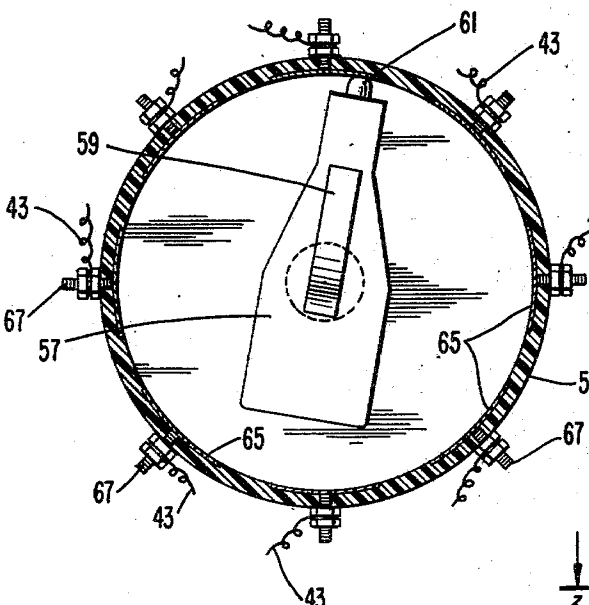


Fig. 3

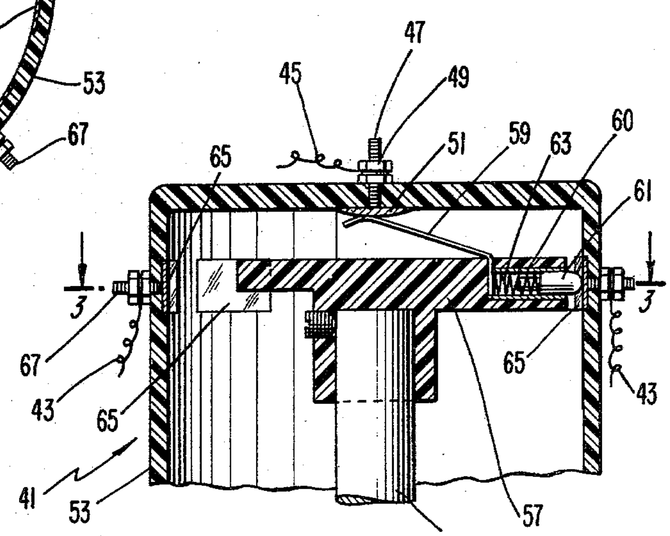


Fig. 2

FIG. 5

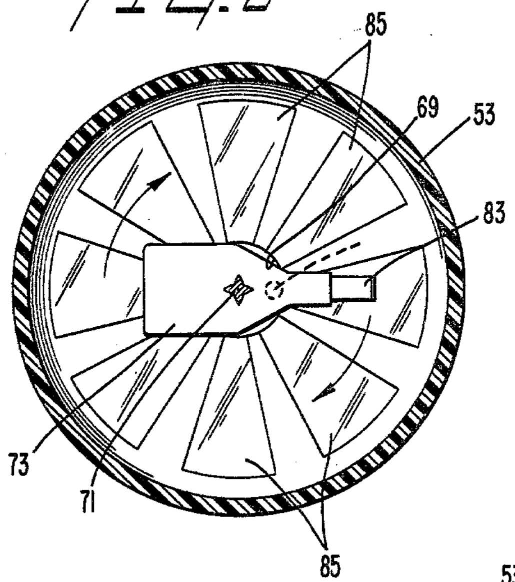


FIG. 4

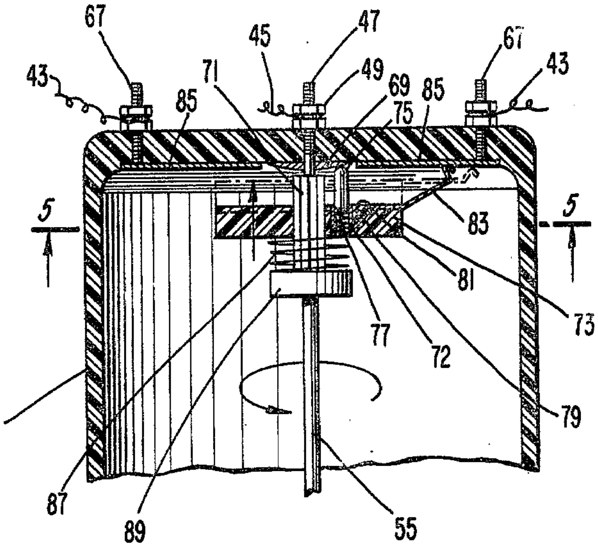
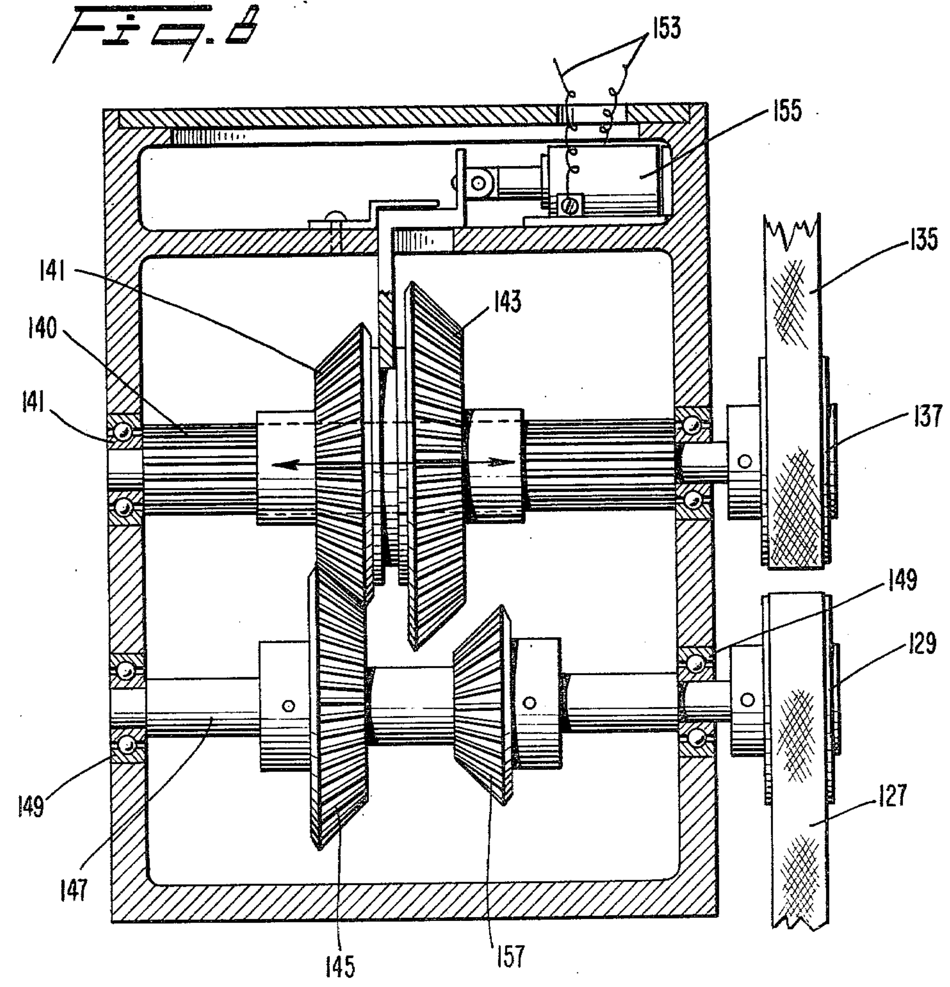


FIG. 6



METHOD AND APPARATUS FOR OPERATING AN ENGINE ON COMPRESSED GAS

BACKGROUND AND SUMMARY OF THE PRESENT INVENTION

The present invention relates to a method and apparatus for operating an engine using a compressed gas as the motive fluid. More particularly, the present invention relates to a apparatus for adapting a pre-existing internal combustion engine for operation on a compressed gas.

Air pollution is one of the most serious problems facing the world today. One of the major contributors to air pollution is ordinary internal combustion engine which are used in most motor vehicles today. Various devices, including many items mandated by legislation, have been proposed in an attempt to limit the pollutants which an internal combustion engine exhausts to the air. However, most of these devices have met with limited success and are often both prohibitively expensive and complex. A clean alternative to the internal combustion engine is needed to power vehicles and other machinery.

A compressed gas, preferably air, would provide an ideal motive fluid for a engine since it would eliminate the usual pollutants exhausted from an internal combustion engine. An apparatus for converting an internal combustion engine for operation on compressed air is disclosed in U.S. Pat. No. 3,885,387 issued May 27, 1975 to Simington. The Simington patent discloses an apparatus including a source of compressed air and a rotating valve actuator which opens and closes a plurality of mechanical poppet valves. The valves deliver compressed air in timed sequence to the cylinders of an engine through adapters located in the spark plug holes. However, the output speed of an engine of this type is limited by the speed of the mechanical valves and the fact that the length of time over which each of the valves remains open cannot be varied as the speed of the engine increases.

Another apparatus for converting an internal combustion engine for operation on steam or compressed air is disclosed in U.S. Pat. No. 4,102,130 issued July 25, 1978 to Stricklin. The Stricklin patent discloses a device which changes the valve timing of a conventional four stroke engine such that the intake and exhaust valves open once for every revolution of the engine instead of once every other revolution of the engine. A reversing valve is provided which delivers live steam or compressed air to the intake valves and is subsequently reversed to allow the exhaust valves to deliver the expanded steam or air to the atmosphere. A reversing valve of this type however does not provide a reliable apparatus for varying the amount of motive fluid injected into the cylinders when it is desired to increase the speed of the engine. Further, a device of the type disclosed in the Stricklin patent requires the use of multiple reversing valves if the cylinders in a multi-cylinder engine were to be fired sequentially.

Therefore, it is an object of the present invention to provide a reliable method and apparatus for operating an engine or converting an engine for operation with a compressed gas.

A further object of the present invention is to provide a method and apparatus which is effective to deliver a

constantly increasing amount of compressed gas to an engine as the speed of the engine increases.

A still further object of the present invention is to provide a method and apparatus which will operate an engine using compressed gas at a speed sufficient to drive a conventional automobile at highway speeds.

It is still a further object of the present invention to provide a method and apparatus which is readily adaptable to a standard internal combustion engine to convert the internal combustion engine for operation with a compressed gas.

Another object of the invention is to provide a method and apparatus which utilizes cool expanded gas, exhausted from a compressed gas engine, to operate an air conditioning unit and/or an oil cooler.

These and other objects are realized by a method and apparatus according to the present invention for operating an engine having at least one cylinder and a reciprocating piston therein using compressed gas as a motive fluid. The apparatus includes a source of compressed gas and a distributor connected with the source of the compressed gas for distributing the compressed gas to the at least one cylinder. A valve is provided for admitting the compressed gas to the cylinder when the piston is in approximately a top dead center position within the cylinder. An exhaust is provided for exhausting the expanded gas from the cylinder as the piston returns to approximately the top dead center position.

In a preferred embodiment of the present invention a device is provided for varying the duration of each engine cycle over which the valve remains open to admit compressed gas to the cylinder dependent upon the speed of the engine. In a further preferred embodiment of the present invention, an apparatus for advancing the timing of the opening of the valve is arranged to admit the compressed gas to the cylinder progressively further before the top dead center position of the piston as the speed of the engine increases.

Further features of the present invention include a valve for controlling the amount of compressed gas admitted to the distributor. Also, a portion of the gas which has been expanded in the cylinder and exhausted through the exhaust valve is delivered to a compressor to be recompressed and returned to the source of compressed gas. A gear train is selectively engagable to drive the compressor at different operating speed depending upon the pressure maintained at the source of compressed air and/or the speed of the engine. Still further, a second portion of the exhaust gas is used to cool a lubricating fluid for the engine or to operate an air conditioning unit.

In a preferred embodiment of the present invention, the valve for admitting compressed gas to the cylinder is electrically actuated. The device for varying the duration of each engine cycle over which the intake valve remains open as the speed of the engine increase comprises a rotating element whose effective length increases as the speed of the engine increases such that a first contact on the rotating element is electrically connected to a second contact for a longer period of each engine cycle. The second contact actuates the valve whereby the valve remains in an open position for a longer period of each engine cycle as the speed of the engine increases.

Still further features of the present invention include an adaptor plate for supporting the distributor above an intake manifold of a conventional internal combustion engine after a carburetor has been removed to allow air

to enter the cylinders of the engine through the intake manifold and conventional intake valves. Another adaptor plate is arranged over an exhaust passageway of the internal combustion engine to reduce the cross-sectional area of the exhaust passageway.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of a method and apparatus for operating an engine according to the present invention will be described with reference to the accompanying drawings wherein like members bear like reference numerals and wherein:

FIG. 1 is a schematic representation of an apparatus according to the present invention arranged on an engine;

FIG. 2 is a side view of one embodiment of a valve actuator according to the present invention;

FIG. 3 is a cross-sectional view taken along the line 3—3 in FIG. 2;

FIG. 4 is a cross-sectional view of a second embodiment of a valve actuator according to the present invention;

FIG. 5 is a view taken along the line 5—5 in FIG. 4;

FIG. 6 is a cross-sectional view of a third embodiment of a valve actuator according to the present invention;

FIG. 7 is a view taken along the line 7—7 in FIG. 6;

FIG. 8 is a cross-sectional view of a gearing unit to drive a compressor according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIG. **1**, an engine block **21** (shown in phantom) having two banks of cylinders with each bank including cylinders **20** having pistons **22** reciprocable therein (only one of which is shown in phantom) in a conventional manner. While the illustrated engine is a V-8 engine, it will be apparent that the present invention is applicable to an engine having any number of pistons and cylinders with the V-8 engine being utilized for illustration purposes only. A compressed gas tank **23** is provided to store a compressed gas at high pressure. It may also be desirable to include a small electric or gas compressor to provide compressed gas to supplement the compressed gas held in the tank **23**. In a preferred embodiment, the compressed gas is air which can be obtained from any suitable source.

A line **25** transports the gas withdrawn from the tank **23** when a conventional shut off valve **27** is open. In addition, a solenoid valve **29** preferably operated by a suitable key operated switch (not shown) for the engine is also arranged in the line **25**. In normal operation, the valve **27** is maintained open at all times with the solenoid valve **29** operating as a selective shut off valve to start and stop the engine **21** of the present invention.

A suitable regulating valve **31** is arranged downstream from the solenoid valve **29** and is connected by a linkage **33** to a throttle linkage **35** which is operator actuated by any suitable apparatus such as a foot pedal (not shown). The line **25** enters an end of a distributor **33** and is connected to an end of a pipe **35** which is closed at the other end. A plurality of holes, which are equal to the number of cylinders in the engine **21**, are provided on either side of the pipe **35** along the length of the pipe **35**.

When the present invention is used to adapt a conventional internal combustion engine for operation on compressed gas, an adaptor plate **36** is provided to support the distributor **33** in spaced relation from the usual intake opening in the intake manifold of the engine after a conventional carburetor has been removed. In this way, air is permitted to enter the internal combustion engine through the usual passageways and to be admitted to the cylinders through suitable intake valves (not shown). The adaptor plate **36** is secured to the engine block **21** and the distributor **33** by any suitable apparatus, e.g., bolts.

Each of the holes in the pipe **35** is connected in fluid-tight manner to a single line **37**. Each line **37** carries the compressed gas to a single cylinder **20**. In a preferred embodiment, each of the lines **37** is $\frac{1}{2}$ inch high pressure plastic tubing attached through suitable connectors to the distributor **33** and the pipe **35**. Each of the lines **37** is connected to a valve **39** which is secured in an opening provided near the top of each of the cylinders **20**. In the case of a conversion of a standard internal combustion engine, the valves **39** can be conveniently screwed into a tapped hole in the cylinder **20** typically provided for a spark plug of the internal combustion engine. In a preferred embodiment, the valves **39** are solenoid actuated valves in order to provide a fast and reliable opening and closing of the valves **39**.

Each of the valves **39** is energized by a valve actuator **41** through one of a plurality of wires **43**. The valve actuator **41** is driven by a shaft of the engine similar to the drive for a conventional distributor of an internal combustion engine. That is, a shaft **55** of the valve actuator **41** is driven in synchronism with the engine **21** at one half the speed of the engine **21**.

A first embodiment of the valve actuator **41** (FIGS. **2** and **3**) receives electrical power through a wire **45** which is energized in a suitable manner by a battery, and a coil if necessary (not shown) as is conventional in an internal combustion engine. The wire **45** is attached to a central post **47** by a nut **49**. The post **47** is connected to a conducting plate **51** arranged within a housing **53** for the valve actuator **41**. Within the housing **53**, the shaft **55** has an insulating element **57** secured to an end of the shaft **55** for co-rotation therewith when the shaft **55** is driven by the engine **21**. A first end of a flexible contact **59** is continuously biased against the conducting plate **51** to receive electricity from the battery or another suitable source. A second end of the contact **59** is connected to a conducting sleeve **60** which is in constant contact with a spring biased contact **61** which is arranged within the sleeve **60**. The contact **61** is biased by a spring **63** which urges the contact **61** towards a side wall of the housing **53**.

With reference to FIG. **3**, a plurality of contacts **65** are spaced from one another and are arranged around the periphery of the housing **53** at the same level as the spring biased contact **61**. Each contact **65** is electrically connected to a post **67** which extends outside of the housing **53**. The number of contacts **65** is equal to the number of cylinders in the engine **21**. One of the wires **43**, which actuate the valves **39**, is secured to each of the posts **67**.

In operation, as the shaft **55** rotates in synchronism with the engine **21**, the insulating element **57** rotates and electricity is ultimately delivered to successive ones of the contacts **65** and wires **43** through the spring biased contact **61** and the flexible contact **59**. In this way, each of the electrical valves **39** is actuated and opened in the proper timed sequence to admit compressed gas to each of the cylinders **20** to drive the pistons **22** therein on a downward stroke.

The embodiment illustrated in FIGS. 2 and 3 is effective to actuate each of the valves **39** to remain open for a long enough period of time to admit sufficient compressed gas to each of the cylinders **20** of the engine **21** to drive the engine **21**. The length of each of the contacts **65** around the periphery of the housing **53** is sufficient to permit the speed of the engine to be increased when desired by the operator by moving the throttle linkage **35** which actuates the linkage **33** to further open the regulating valve **31** to admit more compressed gas from the tank **23** to the distributor **33**. However, it has been found that the amount of air admitted by the valves **39** when using the first embodiment of the valve actuator **41** (FIGS. 2 and 3) is substantially more than required to operate the engine **21** at an idling speed. Therefore, it may be desirable to provide a valve actuator **41** which is capable of varying the duration of each engine cycle over which the solenoid valves **39** are actuated, i.e., remain open to admit compressed gas, as the speed of the engine **21** is varied.

A second embodiment of a valve actuator **41** which is capable of varying the duration of each engine cycle over which each of the valves **39** remains open to admit compressed gas to the cylinders **20** dependent upon the speed of the engine **21** will be described with reference to FIGS. 4 and 5 wherein members corresponding to those of FIGS. 2 and 3 bear like reference numerals. The wire **45** from the electrical source is secured to the post **47** by the nut **49**. The post **47** has a annular contact ring **69** electrically connected to an end of the post **47** and arranged within the housing **53**. The shaft **55** rotates at one half the speed of the engine as in the embodiment of FIGS. 2 and 3.

At an upper end of the shaft **55**, a splined section **71** slidably receives an insulating member **73**. The splined section **71** of the shaft **55** positively holds the insulating member **73** for co-rotation therewith but permits the insulating member **73** to slide axially along the length of the splined section **71**. Near the shaft **55**, a conductive sleeve **72** is arranged in a bore **81** in an upper surface of the insulating element **73** generally parallel to the splined section **71**. A contact **75**, biased towards the annular contact ring **69** by a spring **77**, is arranged within the conductive sleeve **72** in contact therewith. The conductive sleeve **72** also contacts a conductor **79** at a base of the bore **81**.

The conductor **79** extends to the upper surface of the insulating element **73** near an outer periphery of the insulating element **73** where the conductor **79** is electrically connected to a flexible contact **83**. The flexible contact **83** selectively engages a plurality of radial contacts **85** arranged on an upper inside surface of the housing **53**. A weak spring **87** arranged around the splined section **71** engages a stop member **89** secured on the shaft **55** and the insulating element **73** to slightly bias the insulating element **73** towards the upper inside surface of the housing **53** to ensure contact between the flexible contact **83** and the upper inside surface of the housing **53**. As best seen in FIG. 5, the radial contacts **85** on the upper inside surface of the housing **53** are arranged generally in the form of radial spokes extending from the center of the housing **53** with the number of contacts being equal to the number of cylinders **20** in the engine **21**. The number of degrees covered by each of the radial contacts **85** gradually increases as the distance from the center of the upper inside surface of the housing **53** increases.

In operation of the device of FIGS. 4 and 5, as the shaft **55** rotates, electricity flows along a path through the wire **45** down through post **47** to the annular contact member **69** which is in constant contact with the spring biased contact **75**. The electrical current passes through the conductive sleeve **72** to the conductor **79** and then to the flexible contact **83**. As the flexible contact **83** rotates along with the insulating member **73** and the shaft **55**, the tip of the flexible contact **83** successively engages each of the radial contacts **85** on the upper inside of the housing **53**. As the speed of the shaft **55** increases, the insulating member **73** and the flexible contact **83** attached thereto move upwardly along the splined section **71** of the shaft **55** due to the radial component of the splines in the direction of rotation under the influence of centrifugal force. As the insulating member **73** moves upwardly, the flexible contact **83** is bent such that the tip of the contact **83** extends further radially outwardly from the center of the housing **53** (as seen in phantom lines in FIG. 4). In other words, the effective length of the flexible contact **83** increases as the speed of the engine **21** increases.

As the flexible contact **83** is bent and the tip of the contact **83** moves outwardly, the tip remains in contact with each of the radial contacts **85** for a longer period of each engine cycle due to the increased angular width of the radial contacts with increasing distance from the center of the housing **53**. In this way, the length of time over which each of the valves **39** remains open is increased as the speed of the engine is increased. Thus, a larger quantity of compressed gas or air is injected into the cylinders as the speed increases. Conversely, as the speed decreases and the insulating member **73** moves downwardly along the splined section **71**, a minimum quantity of air is injected into the cylinder due to the shorter length of the individual radial contact **85** which is in contact with the flexible contact **83**. In this way, the amount of compressed gas that is used during idling of the engine **21** is at a minimum whereas the amount of compressed gas which is required to increase the speed of the engine **21** to a level suitable to drive a vehicle on a highway is readily available.

With reference to FIGS. 6 and 7, a third embodiment of a valve actuator **41** according to the present invention includes an arcuate insulating element **91** having a first end pivotally secured by any suitable device such as screw **92** to the shaft **55** for co-rotation with the shaft **55**. The screw **92** is screwed into a tapped hole in the insulating element **91** such that a tab **94** at an end of the screw **92** engages a groove **96** provided in the shaft **55**. In this way, the insulating element **91** positively rotates with the shaft **55**. However, as the shaft **55** rotates faster, a second end **98** of the insulating element **91** is permitted to pivot outwardly under the influence of centrifugal force because of the groove **96** provided in the shaft **55**. A spring **93** connected between the second end **98** of the element **91** and the shaft **55** urges the second end of the element **91** towards the center of the housing **53**.

A contact **99** similar to the contact **59** (FIG. 2) is arranged such that one end of the contact **99** is in constant contact with the conducting plate **51** located centrally within the housing **53**. The other end of the contact **99** engages a conductive sleeve **101** arranged in bore **102**. A contact element **95** is arranged in the conductive sleeve **101** in constant contact with the sleeve **101**. The bore **102** is arranged generally parallel to the shaft **55** near the second end of the arcuate insulating

element **91**. The contact **95** is biased by a spring **97** towards the upper inside surface of the housing **53** for selective contact with each of the plurality of radial contacts **85** which increase in arc length towards the outer peripheral surface of the housing **53** (FIG. **6**).

In operation of the device of FIGS. **6** and **7**, as the shaft **55** rotates the arcuate insulating element **91** rotates with the shaft **55** and the second end **98** of the insulating element **91** tends to pivot about the shaft **55** due to centrifugal force. Thus, as the effective length of the contact **95** increases, i.e., as the arcuate insulating element **91** pivots further outwardly, the number of degrees of rotation over which the contact **95** is in contact with each of the radial contacts **85** on the upper inside surface of the housing **53** increases thereby permitting each of the valves **39** to remain open for a longer period of each engine cycle to admit more compressed gas to the respective cylinder **20** to further increase the speed of the engine **21**.

With reference to FIG. **1**, a mechanical advance linkage **104** which is connected to the throttle linkage **35**, advances the initiation of the opening of each valve **39** such that compressed gas is injected into the respective cylinder further before the piston **22** in the respective cylinder **20** reaches a top dead center position as the speed of the engine is increased by moving the throttle linkage **35**. The advance linkage **104** is similar to a conventional standard mechanical advance employed on an internal combustion engine. In other words, the linkage **104** varies the relationship between the angular positions of a point on the shaft **55** and a point on the housing **53** containing the contacts. Alternatively, a conventional vacuum advance could also be employed. By advancing the timing of the opening of the valves **39**, the speed of the engine can more easily be increased.

The operation of the engine cycle according to the present invention will now be described. The compressed gas injected into each cylinder of the engine **21** drives the respective piston **22** downward to drive a conventional crankshaft (not shown). The movement of the piston downwardly causes the compressed gas to expand rapidly and cool. As the piston **22** begins to move upwardly in the cylinder **20** a suitable exhaust valve (not shown) arranged to close an exhaust passageway is opened by any suitable apparatus. The expanded gas is then expelled through the exhaust passageway. As the piston **22** again begins to move downwardly a suitable intake valve opens to admit ambient air to the cylinder. The intake valve closes and the ambient air is compressed on the subsequent upward movement of the piston until the piston reaches approximately the top dead center position at which time the compressed gas is again injected into the cylinder **20** to drive the piston **22** downward and the cycle begins anew.

In the case of adapting a conventional internal combustion engine for operation on compressed gas, a plurality of plates **103** are preferably arranged over an end of the exhaust passageways in order to reduce the outlet size of the exhaust passageways of the conventional internal combustion engine. In the illustrated embodiment, a single plate having an opening in the center is bolted to the outside exhaust passageway on each bank of the V-8 engine while another single plate having two openings therein is arranged with one opening over each of the interior exhaust passageways on each bank of the V-8 engine. A line **105** is suitably attached to each of the adaptor places to carry the exhaust to an appropriate location. In a preferred embodiment, the exhaust lines **105** are 1½" plastic tubing.

In a preferred embodiment, the exhaust lines **105** of one bank of the V-8 engine are collected in a line **107** and fed to an inlet of a compressor **109**. The pressure of the exhaust gas emmanating from the engine **21** according to the present invention is approximately 25 p.s.i. In this way, the compressor **109** does not have to pull the exhaust into the compressor since the gas exhausted from the engine **21** is at a positive pressure. The positive pressure of the incoming fluid increases the efficiency and reduces wear on the compressor **109**. The exhaust gas is compressed in the compressor **109** and returned through a line **111** and a check valve **113** to the compressed gas storage tank **23**. The check valve **113** prevents the flow of compressed gas stored in the tank **23** back towards the compressor **109**.

A suitable pressure sensor **115** is arranged at an upper end of the tank **23** and sends a signal along a line **117** when the pressure exceeds a predetermined level and when the pressure drops below a predetermined level. The line **117** controls an electrically actuated clutch **119** disposed at a front end of the compressor **109**. The clutch **119** is operative to engage and disengage the compressor **109** from a drive pulley **121**. Also, the signal carried by the line **117** actuates a suitable valve **123** arranged on a compressor housing **125** to exhaust the air entering the compressor housing **125** from the line **107** when the clutch **119** has disengaged the compressor **109** from the drive pully **121**.

In a preferred embodiment, when the pressure is the tank **23** reaches approximately 600 p.s.i., the clutch **119** is disengaged and the compressor **109** is deactivated and the valve **123** is opened to exhaust the expanded gas delivered to the compressor **109** from the line **107** to the atmosphere. When the pressure within the tank **23** drops below approximately 500 p.s.i., the sensor **115** sends a signal to engage the clutch **119** and close the valve **123**, thereby operating the compressor **109** for supplying the tank **23** with compressed gas.

The pulley **121** which drives the compressor **109** through the clutch **119** is driven by a belt **127** which is driven by a pulley **129** which operates through a gear box **131**. With reference to FIGS. **1** and **8**, a second pulley **133** on the gear box is driven by a belt **135** from a pulley **137** arranged on a drive shaft **139** of the engine **21**. The pulley **137** drives a splined shaft **140** which has a first gear **141** and a second larger gear **143** arranged thereon for rotation with the splined shaft **140**. The splined shaft **140** permits axial movement of the gears **141** and **143** along the shaft **140**.

In normal operation (as seen in FIG. **8**), the first gear **141** engages a third gear **145** arranged on a shaft **147** which drives the pulley **129**. The shafts **140** and **147** are arranged in suitable bearings **149** arranged at each end thereof. When the speed of the engine **21** drops below a predetermined level, a suitable sensor **151** responsive to the speed of the drive shaft **139** of the engine **21** generates a signal which is transmitted through a line **153** to a solenoid actuator **155** arranged within the gear box **131**. The solenoid actuator **155** moves the first and second gears **141**, **143** axially along the splined shaft **140** to the right as seen in FIG. **8** such that the second, larger gear **143** engages a fourth smaller gear **157** which is arranged on the shaft **147**. The ratio of the second gear **143** to the fourth gear **157** is preferably approximately 3 to 1.

In this way, when the speed of the engine **21** drops below the predetermined level as sensed by the sensor **151** (which predetermined level is insufficient to drive the compressor **109** at a speed sufficient to generate the 500–600 pounds of pressure which is preferably in the tank **23**), the solenoid actuator **155** is energized to slide the gears **143**, **141** axially along the splined shaft **140** so that the second, larger gear **143** engages the fourth, smaller gear **157** to drive the pulley **129** and hence the compressor **109** at a higher rate of speed to generate the desired pressure. When the speed of the engine increases above the predetermined level, in a preferred embodiment approximately 1500 rpm, the solenoid actuator **155** is deactivated by the sensor **151** thereby moving the gears **143** and **141** to the left as seen in FIG. 8 such that the first gear **141** re-engages with the third gear **145** to effectuate a 1 to 1 ratio between the output shaft **139** of the engine **21** and the pulley **129**.

The other bank of the V-8 engine has its exhaust ports arranged with adapter plates **103** similar to those on the first bank. However, the exhaust from this bank of the engine **21** is not collected and circulated through the compressor **109**. In a preferred embodiment, a portion of the exhaust is collected in a line **159** and fed to an enlarged chamber **161**. A second fluid is fed through a line **163** into the chamber **161** to be cooled by the cool exhaust emmanating from the engine **21** in the line **159**. The second fluid in the line **163** may be either transmission fluid contained in a transmission associated with the engine **21** or a portion of the oil used to lubricate the engine **21**. A second portion of the exhaust from the second bank of the V-8 engine is removed from the line **159** in a line **165** and used as a working fluid in an air conditioning system or for any other suitable use.

It should be noted that the particular arrangement utilized for collecting and distributing the gas exhausted from the engine **21** would be determined by the use for which the engine is employed. In other words, it may be advantageous to rearrange the exhaust tubing such that a larger or smaller percentage of the exhaust is routed through the compressor **109**. It should also be noted that since the exhaust lines **105** are plastic tubing, a rearrangement of the lines for a different purpose is both simple and inexpensive.

In operation of the engine of the present invention, the engine **21** is started by energizing the solenoid valve **29** and any suitable starting device (not shown), e.g., a conventional electric starter as used on an internal combustion engine. Compressed gas from the full tank **23** flows through the line **25** and a variable amount of the compressed gas is admitted to the distributor **33** by controlling the regulator valve **31** through the linkage **33** and the operator actuated throttle linkage **35**. The compressed gas is distributed to each of the lines **37** which lead to the individual cylinders **20**. The compressed gas is admitted to each of the cylinders **20** in timed relationship to the position of the pistons within the cylinders by opening the valves **39** with the valve actuator **41**.

When it is desired to increase the speed of the engine, the operator moves the throttle linkage **35** which simultaneously admits a larger quantity of compressed gas to the distributor **33** from the tank **23** by further opening the regulator valve **31**. The timing of the valve actuator **41** is also advanced through the linkage **104**. Still further, as the speed of the engine **21** increases, the effective length of the rotating contact **83** (FIG. 4) or **95** (FIG. 6) increases thereby electrically contacting a wider portion of one of the stationary radial contacts **85** to cause each of the valves **39** to remain open for a longer period of each engine cycle to admit a larger quantity of compressed gas to each of the cylinders **20**.

As can be seen, the combination of the regulating valve **31**, the mechanical advance **104**, and the valve actuator **41**, combine to produce a compressed gas engine which is quickly and efficiently adaptable to various operating speeds. However, all three of the controls need not be employed simultaneously. For example, the mechanical advance **104** could be utilized without the benefit of one of the varying valve actuators **41** but the high speed operation of the engine may not be as efficient. By increasing the duration of each engine cycle over which each of the valves **39** remains open to admit compressed gas to each of the cylinders **20** as the speed increases, conservation of compressed gas during low speed operation and efficient high speed operation are both possible.

After the compressed gas admitted to the cylinder **20** has forced the piston **22** downwardly within the cylinder to drive the shaft **139** of the engine, the piston **22** moves upwardly within the cylinder **20** and forces the expanded gas out through a suitable exhaust valve (not shown) through the adapter plate **103** (if employed) and into the exhaust line **105**. The cool exhaust can then be collected in any suitable arrangement to be compressed and returned to the tank **23** or used for any desired purpose including use as a working fluid in an air conditioning system or as a coolant for oil.

When using the apparatus and method of the present invention to adapt a ordinary internal combustion engine for operation with compressed gas it can be seen that considerable savings in weight are achieved. For example, the ordinary cooling system including a radiator, fan, hoses, etc. can be eliminated since the compressed gas is cooled as it expands in the cylinder. In addition, there are no explosions within the cylinder to generate heat. Further reductions in weight are obtained by employing plastic tubing for the lines which carry the compressed gas between the distributor and the cylinders and for the exhaust lines. Once again, heavy tubing is not required since there is little or no heat generated by the engine of the present invention. In addition, the noise generated by an engine according to the present invention is considerably less than that generated by an ordinary internal combustion engine since there are no explosions taking place within the cylinders.

The principles of preferred embodiments of the present invention have been described in the foregoing specification. However, the invention which is intended to be protected is not to be construed as limited to the particular embodiments disclosed. The embodiments are to be regarded as illustrative rather than restrictive. Variations and changes may be made by others without departing from the spirit of the invention. Accordingly, it is expressly intended that all such variations and changes which fall within the spirit and the scope of the present invention as defined in the appended claims be embraced thereby.

What is claimed is:

1. An apparatus for operating an engine having at least one cylinder and a reciprocating piston therein comprising:

a source of compressed gas;

distributor means connected with the source of compressed gas for distributing the compressed gas to the at least one cylinder;

valve means for admitting the compressed gas to the at least one cylinder when the piston is in approximately a top dead center position within the cylinder;

altering means for increasing the duration of each engine cycle over which the valve means admits compressed gas to the at least one cylinder as the speed of the engine increases; and

exhaust means for exhausting gas as the piston subsequently approaches approximately the top dead center position.

2. The apparatus of claim 1 further comprising control means for controlling the amount of compressed gas admitted to the distributor means.

3. The apparatus of claim 1 wherein the valve means is a solenoid valve secured in an opening in the cylinder above the level of the piston at the top dead center position.

4. The apparatus of claims 1 or 2 further comprising means for advancing the timing of the valve means as the speed of the engine increases such that compressed gas is admitted progressively further before the top dead center position as the speed of the engine increases.

5. The apparatus of claim 4 wherein the means for advancing the timing comprises a mechanical linkage connected to an operator actuated accelerator linkage.

6. The apparatus of claim 1 wherein a portion of the gas exhausted through the exhaust means is compressed in a compressor driven by an output shaft of the engine and is returned to the source of compressed gas.

7. The apparatus of claim 1 wherein a portion of the gas exhausted through the exhaust means is used to cool transmission fluid for a transmission associated with the engine.

8. The apparatus of claim 1 wherein a portion of the gas exhausted through the exhaust means is used as a working fluid in an air conditioning system.

9. The apparatus of claim 6 further comprising first gearing means interposed between the output shaft of the engine and the compressor for increasing the speed at which the compressor is driven.

10. The apparatus of claim 6 further comprising clutch means attached to the compressor both for disengaging the compressor from the output shaft of the engine when a first predetermined pressure at the source of compressed gas is exceeded and for engaging the compressor with the output shaft of the engine when the pressure at the source of compressed gas drops below a second predetermined pressure.

11. The apparatus of claim 9 further comprising means for both disengaging the first gearing means when a predetermined speed of the engine is exceeded and engaging a second gearing means for driving the compressor at a speed slower than the first gearing means when the predetermined speed of the engine is exceeded.

12. The apparatus of claim 1 wherein the valve means is electrically actuated and wherein the altering means comprises:

a rotating member timed with the at least one cylinder and arranged within a housing;

first and second contacts arranged on a first end of the rotating member and on an inside surface of the housing, respectively;

means for increasing the distance of the first contact from the rotational axis of the rotating member as the speed of the engine increases such that the first contact moves radially outwardly within the housing; and

said second contact presenting a longer arc length to the first contact as the distance of the first contact from the rotational axis of the rotating member increases.

13. The apparatus of claim 12 wherein the rotating member comprises an arcuate arm and wherein the means for increasing the distance of the first contact comprises pivotally mounting a second end of the arcuate arm about the axis of rotation of the rotating member and spring means for biasing the first end of the arcuate arm towards a radially inward position whereby the first end of the arcuate arm pivots radially outwardly as the speed of the engine increases.

14. The apparatus of claim 12 wherein the rotating member is axially slidably received on a rotating shaft for co-rotation therewith, said shaft having splines with a radial component in the direction of rotation, and wherein the first contact comprises a flexible contact located on an upper surface of the rotating member, said flexible contact being biased against the inside surface of the housing which carries the second contacts whereby as the speed of the engine increases the rotating member is urged axially along the splined shaft towards the inside surface of the housing such that the flexible contact is forced radially outwardly along the inside surface.

15. The apparatus of claim 12 wherein the second contact comprises of radially extending conductor arranged on an upper inside surface of the housing, said conductor increasing in arc length as the conductor extends radially outwardly from a central portion of the housing.

16. An apparatus for adapting an internal combustion engine for operation with compressed gas, the internal combustion engine having at least one cylinder, a piston reciprocable within the at least one cylinder, intake and exhaust means disposed in the at least one cylinder, and a tapped hole in the at least one cylinder adapted to receive a spark plug, the apparatus comprising:

a source of compressed gas;

distributor means connected with the source of compressed gas for distributing the compressed gas to the at least one cylinder;

valve means arranged in the tapped hole for admitting the compressed gas to the at least one cylinder when the piston is in approximately a top dead center position within the cylinder; and

altering means for increasing the duration of each engine cycle over which the valve means remains open to admit the compressed gas as the speed of the engine increases.

17. An apparatus as in claim 16 further comprising first adapter plate means for supporting the distributor means above an intake manifold of the engine, which adaptor plate means allows ambient air to enter through the intake manifold.

18. The apparatus of claim 16 further comprising second adapter plate means for reducing the exit area of the exhaust means.

19. A method of operating an engine on compressed gas, said engine having at least one cylinder and a piston reciprocable therein comprising the steps of:

delivering compressed gas from a source to a distributor;

distributing the compressed gas to the at least one cylinder;

admitting compressed gas to the at least one cylinder through an intake valve when the piston is at approximately a top dad center position;

increasing the duration of each engine cycle over which compressed gas is admitted to the at least one cylinder as the engine speed increases; and

exhausting the remaining gas when the piston subsequently reaches approximately the top dead center position.

20. The method of claim **19** further comprising the step of controlling the amount of compressed gas which is delivered to the distributor.

21. The method of claim **19** further comprising the step of advancing the timing of the opening of the intake valve as the speed of the engine increases.

22. An apparatus for operating an engine having at least one cylinder and a piston reciprocable therein on compressed gas comprising:

a source of compressed gas;

distributor means connected with the source of compressed gas for distributing the compressed gas to the at least one cylinder;

electrically actuated valve means secured in an opening in the at least one cylinder for selectively admitting compressed gas to the at least one cylinder when the piston is in approximately a top dead center position; and

means for advancing the timing of the valve means as the speed of the engine increases whereby compressed gas is admitted progressively further before the top dead center position as the speed of the engine increases.

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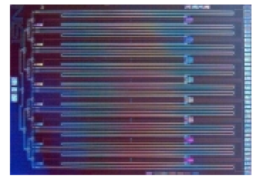
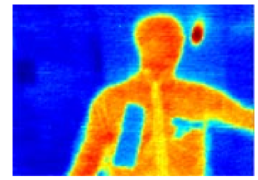
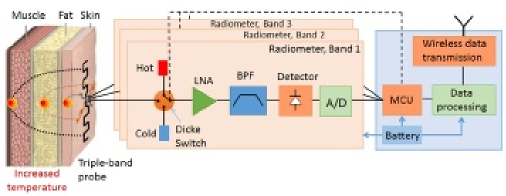
Current Projects





Wearable wireless thermometers for internal body temperature measurements



Funded by: the National Science Foundation
Graduate students: Dr. Robert Scheeler (graduated 2013), Parisa Momenroodaki

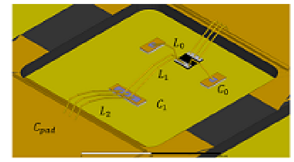
Microwave radiometry is an attractive method for internal thermometry, with the possibility of a wearable device which can continuously monitor temperature inside body tissues in different parts of the body, store the data, and transmit it to a digital medical record. Currently, there are a limited number of available device solutions, and they are usually not wearable or wireless. We are working on a possible path to implementing such a thermometer, with some initial results demonstrating about 0.2K measurement sensitivity and a difference between the maximal and minimal error w.r.t. a thermocouple measurement of 0.5K. Several probes for multi-band radiometers have been developed at frequencies of 410MHz, 1.4, 2.7 and 4.9GHz. The main challenges of RF interference, sensitivity, calibration, spatial resolution, miniaturization, and probe design are discussed. The block diagram of a 3-frequency internal body temperature measurement system is shown in the figure. The power received from tissues layers by the narrowband probes is coupled to the Dicke radiometer circuits, which consists of a switch that is required for calibration, a low-noise amplifier (LNA) followed by band-pass filters and a diode detector circuit. The hot and cold loads are used for continuous temperature calibration of the radiometer. The detector output is a DC voltage which can be integrated over time to increase the signal-to-noise ratio (SNR). This output is digitized, processed and transmitted through a wireless unit. A micro-controller unit (MCU) controls the radiometer switches enabling phase-sensitive detection of the very low human black-body power levels.

In a number of disorders, this temperature difference changes and is not easy to measure externally. For example, long duration of exercise in heat conditions, such as in the case of athletes or soldiers under heavy training, can provoke brain heating leading to premature fatigue and even death. Cancer cells can have increased temperatures, as can inflamed tissues such as joints of arthritis patients. Sleeping disorders are accompanied by changes in the circadian cycle, which are in turn related to changes in phase and amplitude of periodic core body temperature variations. Infants suffering from hypoxia-ischemia have an elevated brain temperature, and if detected can be effectively treated by hypothermic neural rescue. In addition to diagnostics, therapy can be assisted by internal temperature monitoring, e.g. in hyperthermia for cancer treatment and clinical high-intensity focused ultrasound (HIFU) for noninvasive therapy, where the knowledge of local temperature increase would be useful. Applications we are working on include circadian cycle monitoring (with collaborator Dr. Gurley, see http://auraviva.com/circadian-rhythms). We are also working with Speag and ITâ€™IS in the modeling area with the hope of using their virtual population models (see http://www.itis.ethz.ch/news-events/news/latest-news)

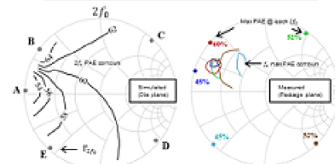
Package Design for Improving Active Device Efficiency

Funded by: Infineon
Graduate students: Sushia Rahimizadeh

Active devices, such as transistors and diodes, are often packaged to allow easier integration with circuit boards. At RF and microwave frequencies, the reactances of the package limit the impedance range that can be presented to the intrinsic device. Additionally, this parasitic reactance is largely capacitive and will limit the harmonic content necessary for achieving high-efficiency operation. In cooperation with Infineon Technologies, packages are designed to present desirable harmonic impedances to the device by using a combination of bond-wires, MOS capacitors, and package parasitics. Accurate full-wave modeling of the passive package environment is demonstrated along with a methodology for manipulating package and bond-wire geometry to achieve specific harmonic impedances. The package model is used in conjunction with harmonic balance simulations including a transistor die non-linear model to design harmonically-terminated packages for highly-efficient power amplifiers at S-band.

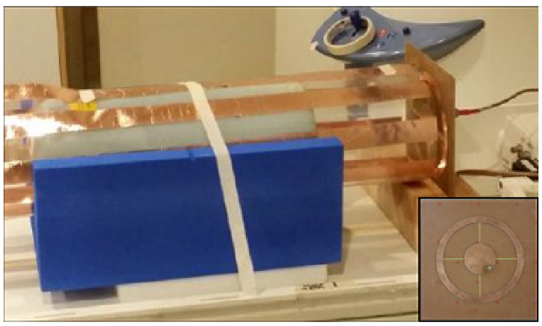


Element	Package Design				
	A	B	C	D	E
L_0 C_0	1.2 nH 0.78 pF	2.0 nH 0.78 pF	1.0 nH 0.32 pF	0.4 nH 0.64 pF	0.7 nH 0.93 pF
L_{pb} 0.8 nH	L_2 1.5 nH	L_1 1.5 nH	C_1 7.11 pF	C_{tab} 5.6 pF	C_{mutual} 0.1 pF



High Field MRI Probes

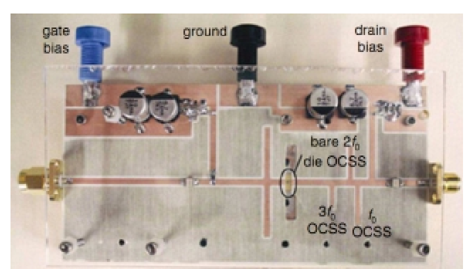
Graduate students: Patrick Bluem



In clinical 1.5 T and 3 T magnetic resonance imaging (MRI) instruments, the object being imaged is closely coupled to the detector through near fields and detection can be viewed as quasi-static. MRI can also be excited and detected using long-range coupling with traveling waves, demonstrated by several research groups over the past few years. One potential benefit of this approach is more uniform coverage of samples that are larger than the wavelength of the NMR signal. Uniform spatial coverage in MRI is traditionally achieved by tailoring the reactive near field of resonant probes. This approach is valid when the radio-frequency wavelength at the Larmor frequency is substantially larger than the target volume, which does not hold for wide-bore high-field systems (>4 T and >60 cm bore diameter). The motivation for using high DC magnetic flux density (B0 > 3 T) is increased spatial resolution, improved SNR, better parallel imaging performance and potential for improved contrast. However, the proton Larmor frequency for hydrogen increases from 64 MHz at 1.5 T to 447 MHz at 10.5 T, resulting in waveguide effects both in the bore and the imaging volume. To help control the excited modes, structures are placed around the imaging volume to modify the boundary conditions.

In collaboration with Harvard University and the Center for Magnetic Resonance Research (University of Minnesota), circular patch probes have been measured on 16.4 T small-bore, 7 T wide-bore, and 10.5 T wide-bore scanners.

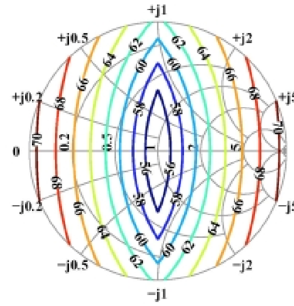
High-efficiency PAs and transmitters for communications, radar and medical applications



The projects in this area are continued work in reducing power consumption in analog front ends with new circuit topologies that give higher efficiency. Our first publications in this area were in 1995, with the first demonstrated microwave-frequency class-E power amplifier. Our results in X-band and UHF power amplifiers had record published efficiencies [ref], and we are continuing a strong effort in this direction at lower microwave frequencies with increased output power. In this area, my group collaborates with the power electronics and analog electronics group at the University of Colorado at Boulder. New directions that we are expanding in is in maintaining linearity [ref] with high efficiency at high power levels, scaling to higher frequencies, increasing the level of integration in advanced materials such as GaN, applying the concept to radar waveforms, etc [ref].

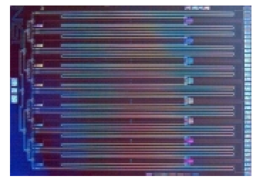
Another related area is intelligent transmitters, which involves sensing, control algorithms, dynamic tuners and dynamic biasing. The tuners can be based on existing electronic technology, or on micro-electromechanical components (RF MEMS) and their packaging and hybrid assembly, and it is a considerable challenge to make these devices practical. An application that would benefit from

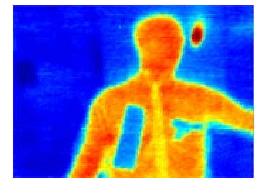
impedance and supply tuning is in medicine for transmitters used in tumor ablation and blood-vessel sealing.



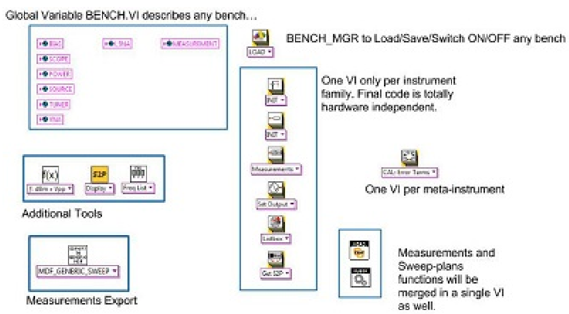
Previous Research

- [LabVIEW Open LSNA]
- [Wireless Powering]
- [DARPA ONR MPC Project]
- [3D Micro-fabricated RF Circuits]
- [FSS]
- [Wind Profiler Radar]





LabVIEW Open LSNA Toolbox



Funded by: National Instruments, CU-Boulder
Developed by: Dr. Tibault Reveyrand

This LabVIEW toolbox enables high level functions on your current instrumentation while presenting high-level abstraction. After defining basic drivers of your instrumentation, the user can conect to power meters, load-pull systems, vectorial receivers and even several calibrated LSNAs with just one polymorphic VI. The toolbox comes with several examples in LabVIEW. One of them is a complete DC power supply sweep and S-parameters measurements dedicated to transistor measurements.

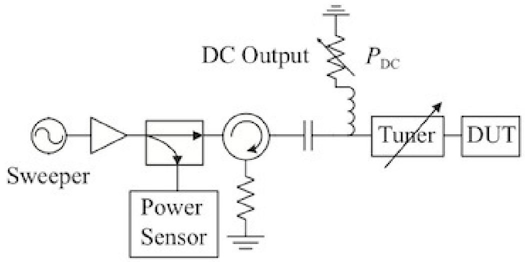
The Large Signal Network Analyzer is an already defined meta-instrument in the toolbox and includes its own calibration procedure. An LSNA can be built without any downconverter, with mixers or sub-samplers.

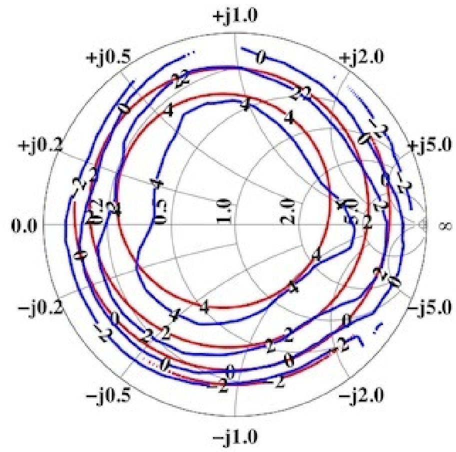
The theory behind the LabVIEW code can be found in the Special Topics course taught by Dr. Reveyrand in Spring 2016.

A version of the toolbox (with proprietary external software removed) can be downloaded here.

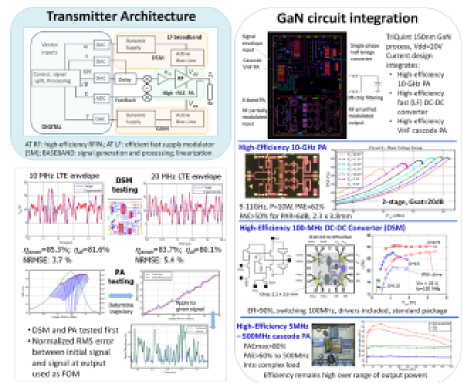
Wireless powering for battery-less sensors

An area in which we have promising initial results, as well as a best paper award, is in RF energy harvesting and wireless powering of wireless sensors. This is an area with a strong collaboration with the Colorado Power Electronics Center (CoPEC), with strengths in low-power management design. The work resulted in a comprehensive patent application and licensing of the IP by several companies, e.g. Cymbet. The applications are for low-maintenance batteryless sensors for manufacturing environments, structural monitoring, and healthcare. We have shown that broadband statistically varying randomly polarized background microwave radiation can be efficiently rectified and the stray energy stored over time for useful electronic applications. We have also shown that FCC-compliant low-power transmitters can be strategically placed to enable constant very low power density energy delivery and storage. Our goals related to this research are to improve the integration of our current hybrid demonstrations, and to expand the circuit-antenna library so that we can address many concrete applications with the best-suited architecture.





DARPA ONR Micro-Power Conversion (MPC) Project



Graduate Researchers: Scott Schafer, Andrew Zai, Michael Litchfield Researchers: Dr. David Sardin and Dr. Tibault Reveyrand Collaborators: CoPEC group at the University of Colorado (http://ecee.colorado.edu/copec/)

The University of Colorado leads a project in integrated GaN microwave transmitters with dynamic supplies, with TriQuint Semiconductor as a subcontractor. We especially thank Dr. Chuck Campbell for technical advice, as well as Maureen Kalinski and John Hitt from TriQuint. We also thank Dr. Dan Green (DARPA) and Dr. Paul Maki from ONR for support competent and thoughtful encouragement along the way, as well as Dr. John Albrecht (formerly DARPA) for the opportunity to work on this project.

The project goals are to:

1. Design 10-GHz transmitter that can efficiently amplify high peak-to-average ratio (PAR) signals
2. Implement transmitter in GaN technology with a high level of integration of RF PA and dynamic power supply (supply modulator)
3. Enable digitally reconfigurable efficient transmission of broadband signals (500MHz) for communications and spectrally confined radar

Our current results for the GaN MMIC PAs measure state-of-the-art PAE>60% at 10GHz with output power >10W and a large signal gain >20dB from a two-stage power-combined architecture in the 150-nm GaN on SiC TriQuint process. In addition, we have demonstrated 70% efficient single stage PAs with watt-level output, and the PAs are designed to maintain efficiency over varying drain supply. The dynamic supplies (supply modulators) are also implemented as MMICs in the same GaN process and show >90% efficiency with 5W output power and 100MHz switching in a 2mm x 2mm chip.

We are interested in both communications signals and radar signals with PAR>7dB. Our test communication signals are typically multi-carrier (OFDM) signals and we have demonstrated supply modulators that can reproduce envelope bandwidths over 300MHz. The supply-modulated transmitters support varying amplitude radar pulses that are frequency modulated, allowing spectral confinement. We are also exploring radar signals with varying pulse shapes and amplitudes on a pulse-to-pulse basis.

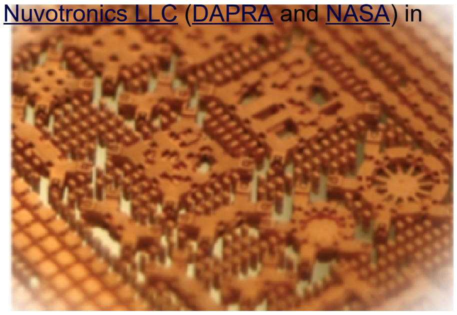
Another aspect of the project have been nonlinear measurements and modeling of the entire system. We have successfully used a time-domain large signal network analyzer to characterize some of the circuits, and have shown that system-level modeling flow can be used to describe the entire system, from base-band to the RF modulated carrier.

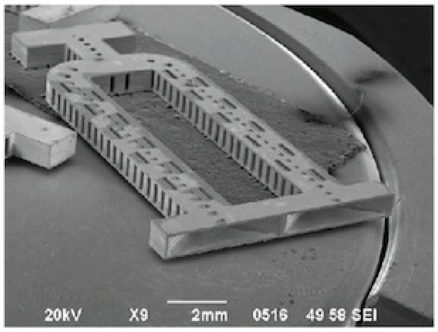
For more information, please see summary program review slides:

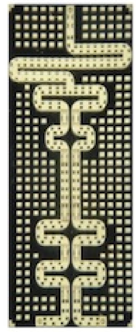
1. UCB MPC Review June 2014
2. UCB MPC Review Feburary 2014

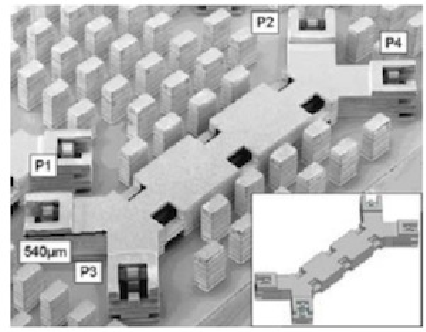
Three-dimensional micro-fabricated microwave and millimeter-wave circuits and antennas

Another active area of research has been in collaboration with Nuvotronics LLC (DAPRA and NASA) in the area of wafer-scale microfabricated coaxial lines and passive and active coaxial-based components. The advantages of these lines, fabricated by Nuvotronics, is extremely low loss into the millimeter-wave range, extremely good isolation of neighboring lines enabling high density circuits, broad bandwidth and low dispersion, and amenability for integration with passive and active surface-mount components. Our research goals are focused on design of completely new components in this technology, in order to push the bandwidth, power handling and flexibility for various communications and sensing applications. Some results include 22:1 bandwidth impedance transformers and 22:1 bandwidth power divider networks which operate up to millimeter-wave frequencies.

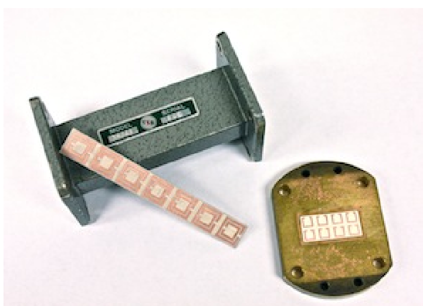








Cryogenic Microwave Radome



In this project, we are developing a layered anisotropic periodic artificial electromagnetic material that increases isolation between transmit and receive antennas of a bistatic radar at 10GHz, while allowing high gain in the receive direction. The receiving antenna is envisioned to be cryogenic for improved gain with small electrical size, and the radome will be thus cooled internally. This allows for low radome loss and the potential of integrating Josephson Junctions for inductive tuning. This project is a collaboration with Dr. Horst Rogalla (NIST and Research Professor at CU), funded by AFOSR.

AWSH.ORG

stuff that i do and things that i make

astatic d-104

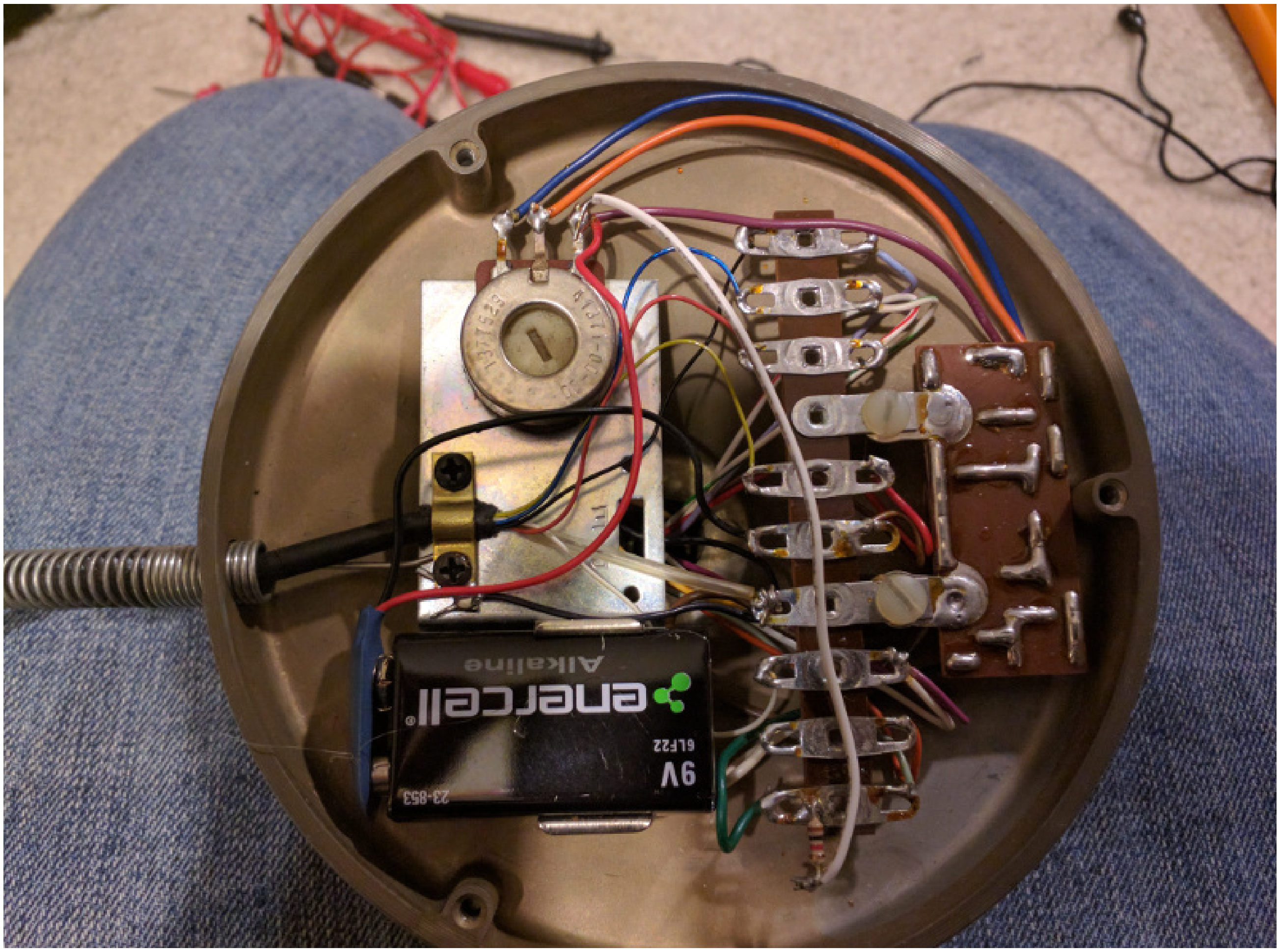
PUBLISHED JULY 31, 2017

I've been keeping my eye out for a mic for the hw-101 for since I got it. I've been partial to the Astatic D-104's, but the prices for them have been too high for my taste. I recently found one on ebay that seemed to be in good condition for a reasonable buy it now price, so I picked it up.

The listing didn't out right say that the mic worked, but I was under the assumption that it did. After messing around with it for about an hour and swapping plugs several

times to try on different radios, I cracked open the mic element. It turns out that crystal was completely disintegrated.

I replaced the crystal element with an electret and soldered in a 1k resistor between the mic line and the 9 volt battery in the base. I stuffed some foam around the electret and closed up the head. In my haste, I didn't get any pictures of the electret/foam, but to be honest there wasn't much to it. There are probably tons of other guides online.



I didn't have a 2 pin mic connector for the hw-101, so I had to settle for testing the mic on an old cb radio. Everything seems to work okay. Once the connectors come in, I'll try it out on the hw-101 and get some audio reports.

PUBLISHED IN **ELECTRONICS** AND **RADIO**

PREVIOUS POST
car stereo aux mod

NEXT POST
ft8

Be First to Comment

Leave a Reply

WELCOME TO THE TRANSISTOR MUSEUM™

DEDICATED TO PRESERVING THE HISTORY OF THE GREATEST INVENTION OF THE 20TH CENTURY

LAST UPDATED June 30, 2017.

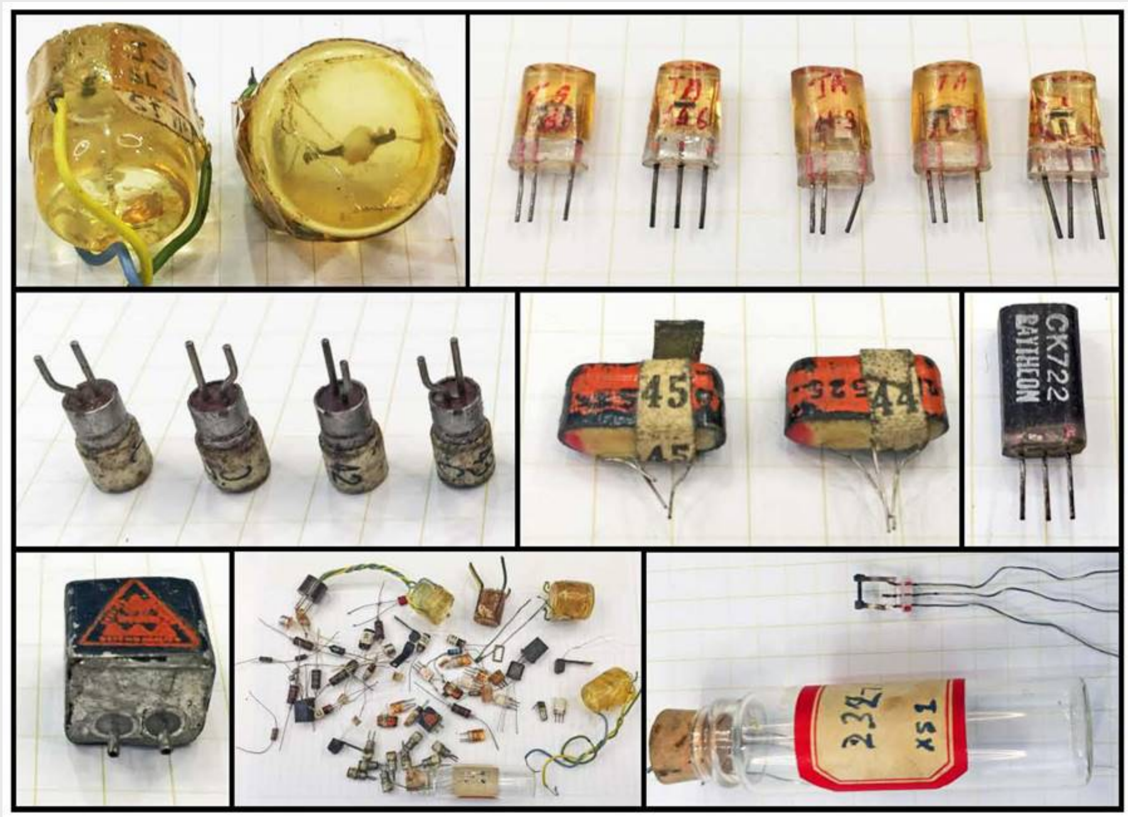
AFTER MANY YEARS ON THE WEB, WE HAVE RE-ORGANIZED THE TRANSISTOR MUSEUM.

The Transistor Museum has grown significantly over the years since we first appeared on the web in 2001. In that timeframe we've added hundreds of pages of unique material specifically developed for those interested in the history of the transistor. In these past 15 years, all areas of the Museum have been expanded, including Oral Histories, Photo Gallery Pictures, Acquisitions and Donations, Photo Essay Research Articles, Construction Projects, Timeline of Transistor History, and many other areas covering topics important to transistor history. In order to help our visitors more easily access the large and still expanding Museum site, we have re-organized this homepage. We'd suggest that our visitors consider using any of the three techniques shown below to quickly access specific types of Museum information related to transistor history:

Use the New Transistor Museum Roadmap
Scroll Down This Homepage for Links to All Museum Areas
Use Google with "Transistor Museum" in the Search String

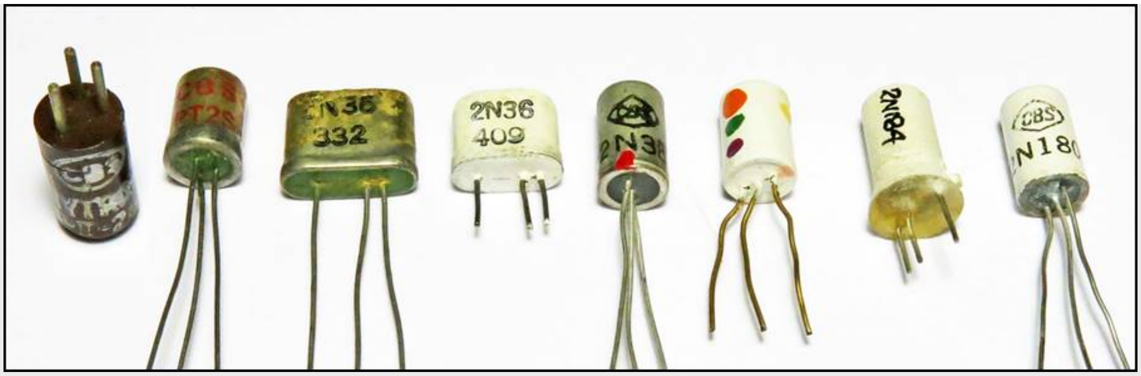
WE ARE CONTINIUNG TO EXPAND, SO CHECK BACK OFTEN. IF YOU'D LIKE TO COMMENT ON THE MUSEUM SITE OR CONSIDER DONATING HISTORIC DEVICES OR DOCUMENTATION, PLEASE USE THIS CONTACT LINK.

NEW AND NOTEWORTHY MATERIAL ADDED TO THE MUSEUM



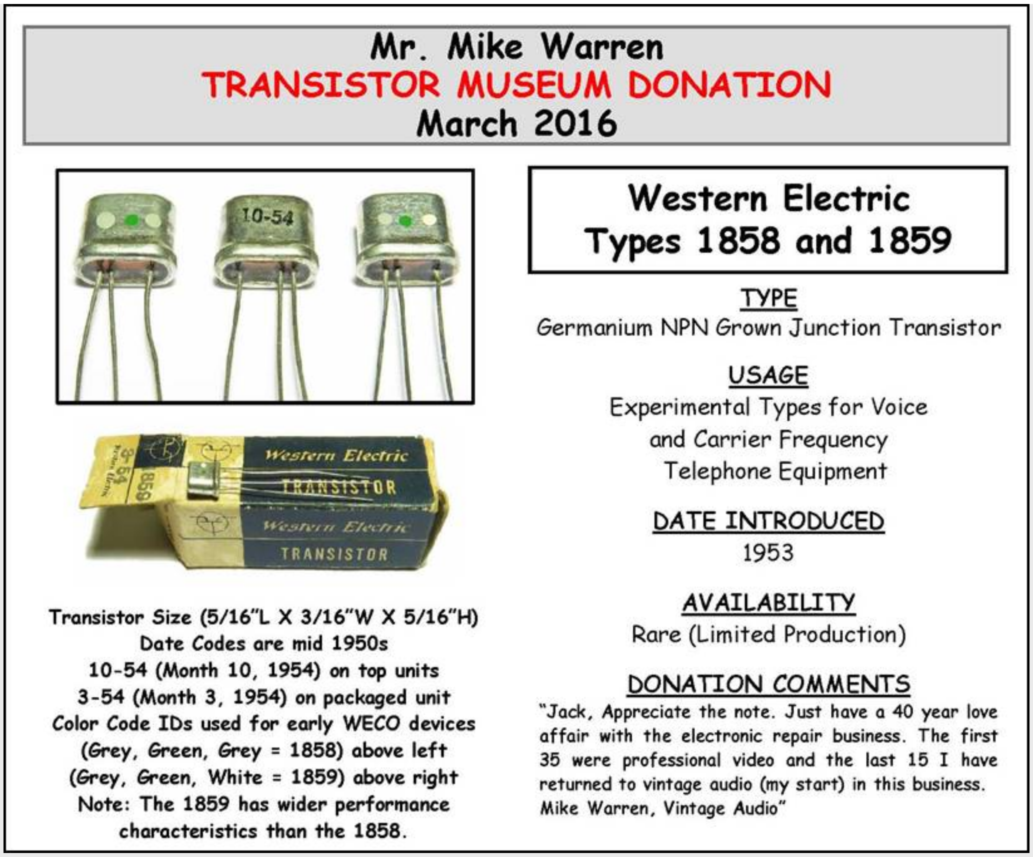
CURATING A WORLD CLASS TRANSISTOR COLLECTION

THE ABOVE PHOTO COLLAGE DOCUMENTS JUST A FEW OF THE MANY HISTORIC TRANSISTORS THAT WERE RECENTLY DONATED TO THE COMPUTER HISTORY MUSEUM. THE CHM, LOCATED IN MOUNTAIN VIEW CA, IS DEDICATED TO THE PRESERVATION AND CELEBRATION OF COMPUTER HISTORY. THIS PHOTOESSAY HAS BEEN PUBLISHED AS PART OF AN ONGOING COLLABORATION BETWEEN THE CHM AND THE TRANSISTOR MUSEUM, AND DOCUMENTS THE HISTORICALLY IMPORTANT BELOTTI SEMICONDUCTOR COLLECTION WHICH WAS DONATED TO THE COMPUTER HISTORY MUSEUM IN LATE 2016. THE TRANSISTOR MUSEUM WISHES TO THANK THE COMPUTER HISTORY MUSEUM, AND ESPECIALLY Dag Spicer, WHO IS THE CHM "CHIEF CONTENT OFFICER" AND David Laws, THE "CHM SEMICONDUCTOR CURATOR", FOR THE OPPORTUNITY TO BE INVOLVED IN THE CURATION OF THIS TRULY HISTORIC LOT OF SEMICONDUCTORS.



CBS HYTRON GERMANIUM COMPUTER TRANSISTORS

BEST KNOWN FOR ITS LONG-LIVED RADIO AND TV NETWORKS, THE COLUMBIA BROADCAST SYSTEM WAS ALSO A MANUFACTURER OF ELECTRON TUBES AND SEMICONDUCTORS. THE CBS "HYTRON" DIVISION WAS ONE OF THE ORIGINAL LICENSEES OF TRANSISTOR TECHNOLOGY FROM WESTERN ELECTRIC AND BEGAN PRODUCTION OF POINT CONTACT TRANSISTORS IN 1953. ALTHOUGH CBS EXITED THE SEMICONDUCTOR BUSINESS IN THE EARLY 1960S, THIS HISTORIC COMPANY DID PRODUCE COMPUTER SWITCHING AND POWER TRANSISTORS FOR MANY OF THE FIRST TRANSISTORIED DIGITAL COMPUTERS. THIS PHOTO ESSAY EXPANDS OUR ONGOING EFFORTS TO DOCUMENT HISTORIC EARLY GERMANIUM COMPUTER TRANSISTORS. CHECK BACK OFTEN AS THIS PROJECT GROWS.

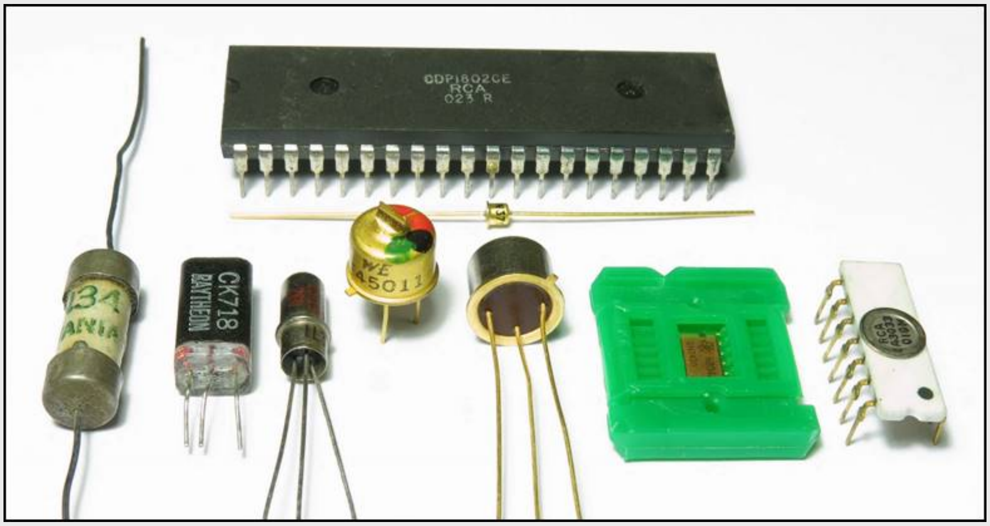


[HISTORIC 1954 WESTERN ELECTRIC 1858/59 TRANSISTORS]

MIKE WARREN'S RECENT DONATION OF EARLY WECO GERMANIUM TRANSISTORS PROVIDES INSIGHT INTO ONE OF THE FIRST INDUSTRIAL USES OF TRANSISTORS. FOLLOW THE LINK ABOVE TO LEARN ABOUT THIS HISTORIC TECHNOLOGY.

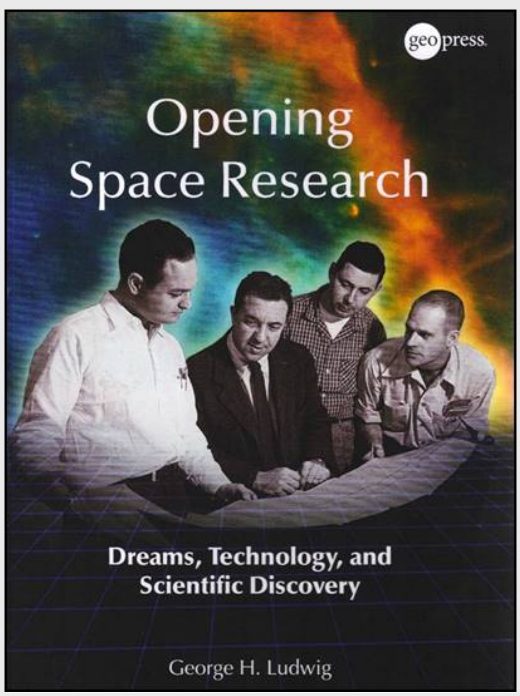
THE TRANSISTOR MUSEUM IS VERY PLEASED TO HAVE BEEN RECENTLY SELECTED BY THE VENERABLE TUBE COLLECTORS ASSOCIATION AS THE RECIPIENT OF THE 2015 SCHRADER AWARD. THIS PRESTIGIOUS AWARD RECOGNIZES EXCELLENCE IN PRESERVING TUBES AND ASSEMBLING THEM INTO A COMPREHENSIVE COLLECTION.
MORE INFORMATION ABOUT TCA CAN BE FOUND AT:

TUBE COLLECTORS ASSOCIATION



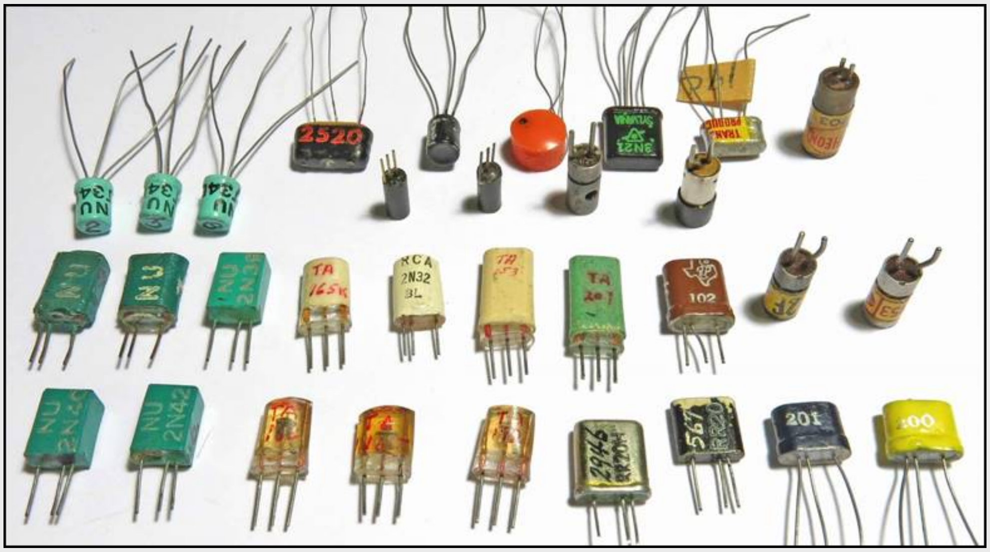
A BRIEF HISTORY OF EARLY SEMICONDUCTORS

LEARN ALL ABOUT THE HISTORY OF DIODES, TRANSISTORS AND ICs, BEGINNING WITH THE FIRST CAT WHISKER DETECTORS IN 1906. LOTS OF PHOTOS AND TECHNICAL INFORMATON.
YOU CAN ALSO START YOUR OWN HISTORIC SEMICONDUCTOR COLLECTION WITH THIS NEW TRANSISTOR MUSEUM RESEARCH KIT.



A TRANSISTOR MUSEUM BOOK REVIEW:
OPENING SPACE RESEARCH BY GEORGE H. LUDWIG

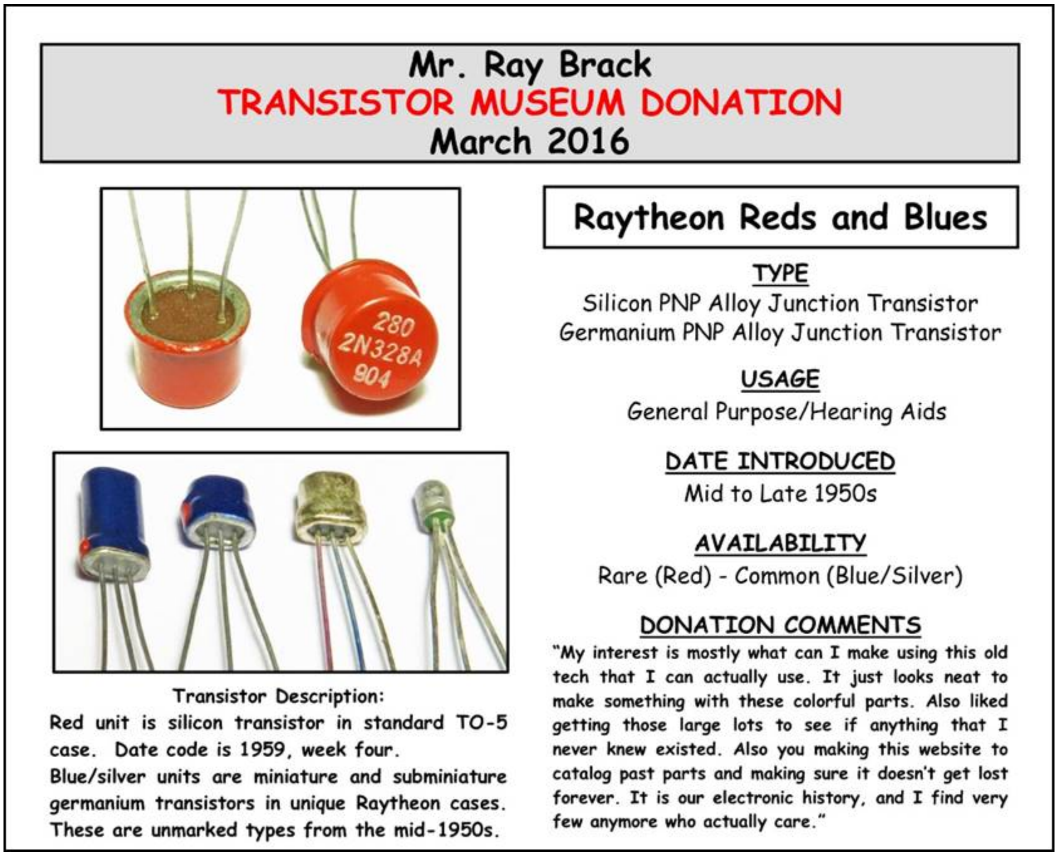
LEARN ABOUT THE FIRST TRANSISTORS IN SPACE. A NEW TRANSISTOR MUSEUM BOOK REVIEW OF GEORGE LUDWIG'S PERSONAL ACCOUNT OF HIS TRANSISTOR DESIGNS USED IN THE FIRST U.S. SATELLITES - VANGUARD AND EXPLORER.



HISTORIC 1950s GERMANIUM COMPUTER TRANSISTORS

A NEW DONATION AND PHOTO ESSAY OF A UNIQUE COLLECTION OF HISTORIC 1950s GERMANIUM COMPUTER TRANSISTORS FROM JONATHAN HOPPE.

ACQUISITIONS AND DONATIONS OF HISTORIC SEMICONDUCTORS

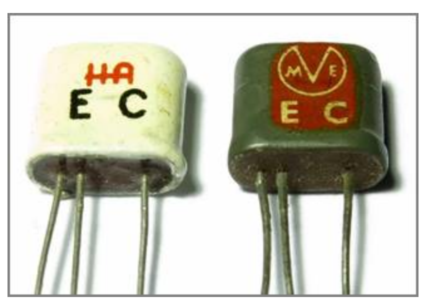


[Raytheon 1950s Reds and Blues]

Donated by Ray Brack

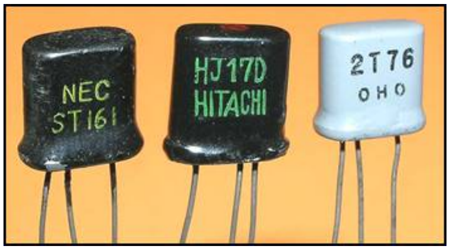
[Western Electric Type 3A Germanium Photo Transistor]

Donated by Dave Pansen



[1950s Marvelco J-2 Germanium Alloy Junction Transistor]

Donated by Robert Cruz

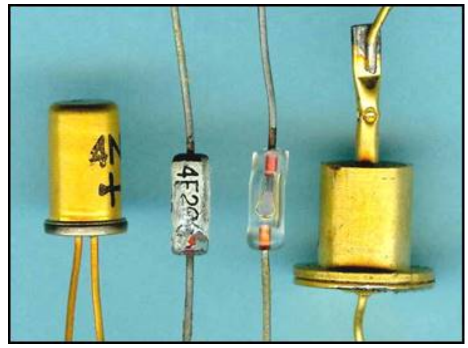


Early Germanium Transistors from Japan
Vintage: Late 1950s
Donated by Masahiro Nakahori

These three transistors in the photo have been donated to the Transistor Museum by Masahiro Nakahori. Mr. Nakahori is a Japanese engineer with a strong interest in transistor history and has developed an extensive collection of these unique devices. Sony was the first Japanese company to purchase a license to manufacture transistors from Western Electric, beginning in the mid-1950s. The Sony 2T76 shown in the photo is from 1957 and illustrates the case style and color used by Sony for its original commercial transistors. The Sony 2T76 and the NEC ST161 are NPN grown junction types equivalent to the American TI 2N147 – used in early radios as an IF amplifier. The Hitachi HJ17D is a PNP alloy junction type, equivalent to an RCA 2N217.

[Visit the Transistor Museum Photo Gallery for More Info on the 2T76]

[Visit Masahiro's Superb Historic Semiconductor Website]



Shockley 4 Layer Transistor Diodes
Vintage: Late 1950s
Donated by Ludwell Sibley

In 1956, William Shockley established the Shockley Semiconductor Laboratories at 391 South Antonio Road in Palo Alto, Ca. This was the first semiconductor company established in what would later be known as Silicon Valley. Shockley's primary product was the 4 layer diode, also known as the Shockley diode or the transistor diode. Samples of these 45+ year old devices, shown in the photo above, have recently been donated by Ludwell Sibley. Lud is quite well known as an authority/collector of vacuum tubes, and has been kind enough to provide these solid state devices to the museum. Use the two links below to learn more about Lud's work, and also to learn more about Shockley diodes.

[http://www.tubecollectors.org/]

[Shockley (4 Layer Diodes) Photo Essay]

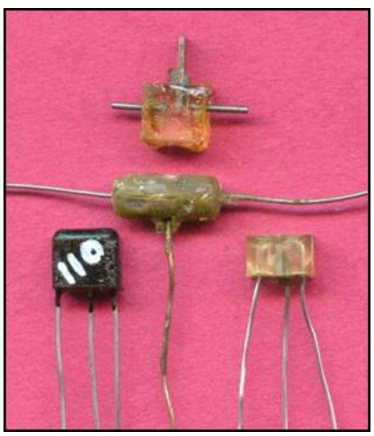
Soviet Type C2A Germanium

Signetics NE555
Integrated Circuit Prototypes
Vintage: 1971
Donated by Hans Camenzind

The 555 timer IC is the most successful integrated circuit yet designed, as measured by the number of units sold (billions) and the longevity of the original design (unchanged since 1971). The devices in the above photo are working prototypes from the initial pilot run at Signetics in 1971, and have been donated to the Museum by Hans Camenzind - the designer of the historic 555 integrated circuit. You'll learn all the details about the design and development of this unique IC in the Hans Camenzind Oral History.

Point Contact Transistor
Vintage: 1950s
Donated by Nikolai Pavlov

Commercial Soviet transistors became available in the mid-1950s. These first devices were germanium, and represented both of the major types of transistors available worldwide at the time - junction and point contact. The point contact type quickly became obsolete and limited numbers were manufactured. Above is a 1957 type C2A Soviet point contact transistor, shown next to a classic Western Electric A1729 point contact transistor from the early 1950s. Early Soviet transistor development is poorly documented in the West, and devices of this type are very rare.



Hughes Experimental Germanium
Coaxial Point Contact Transistors
Vintage: 1949
Donated by Sanford Barnes

These devices are very historic, and are the earliest examples of transistors currently on display at the museum. In 1949 Mr. Sanford Barnes began work at Hughes Aircraft as an engineer in the newly formed transistor development group. His assignment was to investigate the potential for the use of transistor technology in Hughes' aircraft applications. These four devices were made by Mr. Barnes in an effort to

Motorola Germanium Prototypes
Vintage: Early to Mid 1950s
Donated by Craig Carter

Motorola became a dominant transistor manufacturer in the late 1950s, with primary success related to germanium power transistor devices, such as the 2N176, intended for use in the rapidly expanding automobile radio market. Prior to large scale commercialization, Motorola engineers developed experimental prototype devices, two of which are shown above. The larger blue transistor is a five watt experimental germanium power transistor from 1955. The smaller device is an EP-7 experimental point contact transistor, likely developed in the early 1950s as Motorola first began investigating the

evaluate the suitability of coaxial, or opposed surface, point contact transistors which had been recently developed at Bell Labs. You can read about this pioneering work in the Sanford Barnes Oral History.

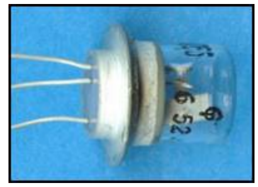
new transistor technology. Thanks to Craig Carter for making these unique and historic semiconductors available to the museum. You can learn more about these devices through these links:

Motorola Germanium Power Prototype

Motorola EP-7

Delco Germanium Power Transistor
Vintage: 1963
Donated by Ray Brack

Beginning in the mid-1950s, Delco established an active transistor program. This effort resulted in the production of millions of germanium transistors, primarily intended for the automobile radio market. Most notable were germanium power transistors designed for car radio audio output – as shown above, the quantity of this type of transistor manufactured by Delco reached 25 million in 1963. Many thanks to Ray Brack for donating this unique device. Ray has been active in the designing and repairing electronic equipment for many years, and he has been saving the device shown above for a long time, hoping to find an appropriate museum.



General Transistor Company GT66, 2N318
Germanium Photo Transistor
Vintage: 1956
Donated by Dennis Uhlich

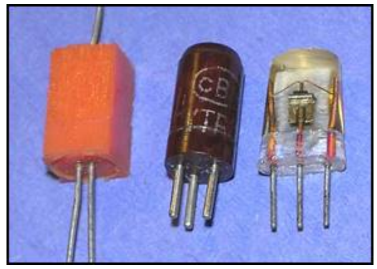
General Transistor Corporation was a premier manufacturer of germanium alloy junction transistors in the latter part of the 1950s. The company was founded by engineers and managers who had originally been associated with another early transistor manufacturer, Radio Receptor. One of the most unique and historic germanium transistor devices was the photo transistor, and General Transistor was a primary supplier, with the product sold initially as the GT66 and later as the 2N318. This device is very similar to the Radio Receptor RR66 photo transistor. The above device (note date code of 1956, week 52) has been donated to the Transistor Museum by Dennis Uhlich, who was convinced that this was a unique device, although there wasn't much research information available on the internet. Dennis' contribution included the device, along with a comprehensive data sheet. You can learn more about the history of this type of phototransistor with these links:

Art Rossoff Oral History

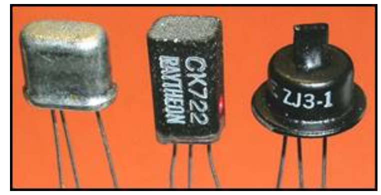
Historic 1951 Raytheon CK716
Point Contact Transistor
Donated by Bob Varga

PhotoGallery Link to RR66 Phototransistor

Germanium PNP Alloy Junction, serial# A-5043
RCA TA-153 Developmental Transistor



Point Contact Transistors
Left: Westinghouse WX3347
Middle: CBS PT-2A
Right: RCA TA-165



Early Germanium Transistors
Left: Western Electric 1858 NPN Grown Junction
Middle: Raytheon CK722 PNP Alloy Junction
Right: GE Type ZJ3-1

Historic Prototype and Early Production Germanium Transistors
Vintage: 1952/1953
Donated by Dave Larson

Transistor technology was evolving rapidly in the 1950s, and many companies developed intriguing experimental and prototype devices as the design and manufacturing technologies matured. The transistors shown above are historically interesting devices that provide an excellent overview of the widely varied case styles and construction technologies of the very early production and prototype processes. Many thanks to Dave Larson for the generous donation to the museum of these transistors (and a number of other related devices). Dave also provided these comments: "Thanks for the info. I am glad they are in a safe place where they will be archived for future generations to enjoy! As far as the reference to the donor. Please put them in memory of my father Meyer H. Axler, who worked on early transistor development projects at Bell Labs and Baird Atomic. I am looking forward to seeing them on the virtual museum. Thanks for all you are doing on behalf of early research scientists like my father."

PHOTO ESSAYS AND TRANSISTOR MUSEUM ORIGINAL RESEARCH ARTICLES ON TECHNOLOGIES, COMPANIES AND PEOPLE IMPORTANT TO THE EARLY HISTORY OF TRANSISTORS

THE TRANSISTOR MUSEUM IS CURRENTLY DEVELOPING A SERIES OF PHOTOESSAYS ON GERMANIUM COMPUTER TRANSISTORS. DIGITAL

COMPUTERS FROM THE 1950S AND 1960S WERE THE FIRST COMPUTERS TO USE TRANSISTORS AND THIS ONGOING PROJECT WILL DOCUMENT THE MAJOR IMPACT OF EARLY TRANSISTOR TECHNOLOGY ON COMPUTER DEVELOPMENT.
FOLLOW THESE LINKS TO SEE COMPLETED CHAPTERS:

HISTORIC GENERAL ELECTRIC GERMANIUM COMPUTER TRANSISTORS

HISTORIC GENERAL TRANSISTOR GERMANIUM COMPUTER TRANSISTORS

HISTORIC IBM GERMANIUM COMPUTER TRANSISTORS

HISTORIC PHILCO GERMANIUM COMPUTER TRANSISTORS

HISTORIC RAYTHEON GERMANIUM COMPUTER TRANSISTORS

HISTORIC SYLVANIA GERMANIUM COMPUTER TRANSISTORS

A SURVEY OF EARLY POWER TRANSISTORS:
JOE A. KNIGHT HAS DEVELOPED A COMPREHENSIVE HISTORY OF THE FIRST GERMANIUM AND SILICON POWER TRANSISTORS, FROM THE 1950s/1960s. INCLUDES EXTENSIVE PHOTOGRAPHY.
A SURVEY OF EARLY POWER TRANSISTORS BY JOE A. KNIGHT

HERE IS A NEW PHOTOGALLERY ARTICLE.
LEARN ABOUT THE VANGUARD I SATELLITE AND THE EXCITING 1958 TRANSISTOR TECHNOLOGY THAT POWERED THE RADIO TRANSMITTERS IN THIS HISTORIC SATELLITE.
WESTERN ELECTRIC GA-53233 AND GF-45011
1950s VANGUARD TRANSISTORS

THE TRANS-AIRE RADIO STORY:
A 1950s/60s U.S. COMPANY MAKES GOOD USE OF THOUSANDS OF REJECT TRANSISTORS FROM RAYTHEON, GE AND FAIRCHILD.
A TRANSISTOR MUSEUM INTERVIEW WITH JOE D'AIRO

RECOLLECTIONS OF EARLY TRANSISTOR RADIO TECHNOLOGY AT ZENITH RADIO CORPORATION.
A TRANSISTOR MUSEUM INTERVIEW WITH RAY ANDREJASICH

THE FIRST RCA TRANSISTOR RADIOS:
TOM STANLEY RECOUNTS MANY OF THE EXCITING AND AS YET UNPUBLICIZED ASPECTS OF THE WORK AT RCA LABS IN THE 1950s ON EARLY TRANSISTOR DEVICES AND APPLICATIONS.

A TRANSISTOR MUSEUM INTERVIEW WITH THOMAS O. STANLEY

ON SEPT 18, 1956, GUS FALLGREN OF CHELMSFORD MA. COMPLETED THE FIRST DOCUMENTED TRANS-ATLANTIC AMATEUR RADIO CONTACT USING A “TRANSISTOR-POWERED” TRANSMITTER.

A TRANSISTOR MUSEUM INTERVIEW WITH GUS FALLGREN (W1OG), AL HANKINSON (KC3QU) AND DICK WRIGHT (W1UC)

STARTING IN 1955, RAYTHEON PRODUCED A SERIES OF IRIDESCENT, BRIGHT BLUE GERMANIUM TRANSISTORS. HERE IS THE HISTORY OF THESE UNIQUE TRANSISTORS.

"RAYTHEON BLUES" PHOTO ESSAY

TEXAS INSTRUMENTS INTRODUCED THE FIRST COMMERCIAL SILICON TRANSISTORS IN 1954. BILL BROWER WORKED AS AN ENGINEER WITH THESE HISTORIC DEVICES AND PROVIDES TECHNICAL DETAILS AND PERSONAL RECOLLECTONS.

A TRANSISTOR MUSEUM INTERVIEW WITH BILL BROWER

A TRULY HISTORIC TECHNOLOGY - THE “SHOCKLEY DIODE” WAS DEVELOPED IN THE LATE 1950s AT THE SHOCKLEY SEMICONDUCTOR LABORATORIES, THE FIRST SILICON VALLEY COMPANY.

SHOCKLEY (4 LAYER) DIODE PHOTO ESSAY

THE METAL CARTRIDGE VERSION OF THE ORIGINAL POINT CONTACT TRANSISTOR (DESIGNATED “TYPE A”) WAS DEVELOPED AT BELL LABS IN 1948, AND WAS THE FIRST TRANSISTOR ROBUST ENOUGH TO BE MANUFACTURED IN QUANTITY.

BELL LABS "TYPE A" POINT CONTACT TRANSISTOR PHOTO ESSAY

THE PLASTIC BEAD TYPE POINT CONTACT TRANSISTOR REPRESENTS AN IMPORTANT MILESTONE IN TRANSISTOR HISTORY, DEVELOPED IN THE EARLY 1950s AS A POTENTIAL LOW COST ALTERNATIVE TO THE INITIAL METAL CATRIDGE “TYPE A”.

BELL LABS "BEAD TYPE" POINT CONTACT TRANSISTOR PHOTO ESSAY

THE PLASTIC BEAD TYPE POINT CONTACT TRANSISTOR REPRESENTS AN IMPORTANT MILESTONE IN TRANSISTOR HISTORY, DEVELOPED IN THE EARLY 1950s AS A POTENTIAL LOW COST ALTERNATIVE TO THE INITIAL METAL CATRIDGE "TYPE A".

BELL LABS "TYPE M1752" GERMANIUM GROWN JUNCTION TRANSISTOR

THE EARLY HISTORY OF TRANSISTORS IN GERMANY: RUDI HERZOG HAS DEVELOPED A COMPREHENSIVE HISTORY OF THE FIRST TRANSISTORS IN GERMANY, STARTING 1952.

THE EARLY HISTORY OF TRANSISTORS IN GERMANY BY RUDI HERZOG

ARTHUR L. ROSSOFF IS CO-AUTHOR OF THE INFLUENTIAL TEXT *TRANSISTOR ELECTRONICS* PUBLISHED IN 1957 BY MCGRAW HILL. IN THIS INTERVIEW, ART PROVIDES HIS PERSPECTIVE ON 1950s TRANSISTOR TECHNOLGY AS DOCUMENTED IN THIS HISTORIC TEXT.

A TRANSISTOR MUSEUM INTERVIEW WITH ART ROSSOFF

TRIBUTE COMMENTARY FOR TWO MAJOR CONTRIBUTORS TO THE HISTORY OF SEMICONDUCTORS

IN TRIBUTE TO MR. HANS CAMENZIND, WHO PASSED AWAY ON AUGUST 15, 2012.

HANS CAMENZIND MEMORIAL COMMENTARY

HERE IS THE ORIGINAL 2004 TRANSISTOR MUSEUM ORAL HISTORY

HANS CAMENZIND - THE INVENTOR OF THE LEGENDARY 555 TIMER IC

AUDIO CLIPS OF THE 2004 TRANSISTOR MUSEUM INTERVIEW

HANS CAMENZIND AUDIO CLIPS FROM 2004 INTERVIEW

IN TRIBUTE TO MR. NORMAN KRIM, WHO RECENTLY PASSED AWAY AT THE AGE OF 98.

NORMAN KRIM - THE FATHER OF THE CK722 TRANSISTOR

AUDIO CLIPS OF THE 2000 TRANSISTOR MUSEUM INTERVIEW

NORMAN KRIM AUDIO CLIPS FROM 2000 INTERVIEW

HERE IS A NEW CK722 ADVENTURE OF CARL AND JERRY.
RE-IMAGINED FROM 1953.
CARL AND JERRY WITH THEIR FIRST CK722

HERE IS THE MARCH 2003 IEEE SPECTRUM ARTICLE BY HARRY GOLDSTEIN ABOUT NORMAN KRIM
AND HIS PIONEERING WORK AT RAYTHEON.
IEEE SPECTRUM - THE IRRESISTABLE TRANSISTOR

ORAL HISTORIES

This area of the Transistor Museum™ may be the most useful and informative for those visitors who are interested in the history of transistors. Here you'll find first-hand and personal accounts from those engineers and scientists who were actually involved in creating and advancing this remarkable technology.

BERNARD REICH

CHIEF OF DEVICE ENGINEERING FOR THE U.S. ARMY SIGNAL CORPS IN THE 1950s/1960s

Soon after the June 1948 public announcement of the invention of the transistor by Bell Labs, the U.S. military actively promoted the industrial development of this technology for military use. Throughout the 1950s and 1960s, the Signal Corps established and funded hundreds of industry contracts with transistor companies to assure availability of specific transistor types meeting military requirements. Bernard Reich was actively involved in this historic Signal Corps work and has authored

BILL GUTZWILLER

THE 1950s DEVELOPMENT OF THE SILICON CONTROLLED RECTIFIER (SCR) AND THE TRIAC AT GE

During a 30+ year career at GE, Bill Gutzwiller made substantial contributions to the field of power semiconductor applications and devices, especially the silicon controlled rectifier (SCR) and the Triac. You'll learn all about the development of these historic devices from Bill's firsthand experiences and recollections. If you've designed an SCR or Triac circuit, studied these devices at school, or marveled at the wealth of material contained in any of the numerous volumes of the famous GE SCR manuals, then you've benefited from Bill's work.

numerous articles documenting important early transistor types.

DAVID BAKALAR

FOUNDING THE HISTORIC SEMICONDUCTOR COMPANY "TRANSITRON" IN 1952

Founded in 1952 by David and Leo Bakalar in an old mill in Wakefield Massachusetts, Transitron Electronic Corporation became one of the most successful semiconductor manufacturing companies in the world within a few short years. By the mid to late 1950s, Transitron was in the top two or three U.S. producers of diodes, rectifiers and transistors. David Bakalar was the president of Transitron from 1952 to 1984 and his substantial technical achievements with the development of such breakthrough semiconductor devices as gold bonded germanium diodes and silicon rectifiers were the primary basis for Transitron's success. This Transistor Museum™ Historic profile will provide historical information on Transitron's early semiconductor technology, as well as recent comments from David Bakalar about his pioneering semiconductor work and accomplishments over 50 years ago.

BOB SLADE

RCA'S FIRST TRANSISTOR ENGINEER AND STARTING UP PRODUCTION OF POINT CONTACT TRANSISTORS

Bernard (Bob) Slade began his career in semiconductor technology in 1948 when he became the first RCA "transistor engineer", and has made major contributions to the semiconductor field since that time. His early work at RCA led to the 1953 introduction of the 2N32 and 2N33 point contact transistors. Bob joined IBM in 1956 where he was responsible for establishing the first germanium transistor production facility for that company. He remained at IBM for 28 years and managed the computer semiconductor production transition from germanium alloy transistors to silicon integration. This Oral History provides an detailed look at Bob's impressive contributions to early transistor history at RCA, including point contact transistor research and early germanium power transistor development.

LEN BUCKWALTER

AUTHOR OF CLASSIC AND WELL REMEMBERED 1960s AND 1970s TRANSISTOR BOOKS AND ARTICLES

Mr. Len Buckwalter's technical publications from the 1960s and 1970s have had a major impact on many of us who were first involved with transistor technology during that time. He authored dozens of transistor construction project articles that appeared in Electronics Illustrated magazine, where he was active as a technical editor and column author. Len may best be remembered for his now legendary books from the 1960s that were written primarily for the young

RICHARD S. BURWEN

PIONEER IN EARLY TRANSISTOR HI-FI AND AUDIO CIRCUIT DESIGN

For over 60 years, Dick Burwen has been actively involved in the electronics industry, with noted accomplishments in the field of audio circuit design. Since building his own amateur radio station (W1NMG) as a youth in the 1940s, Dick's prolific career has paralleled the growth of the semiconductor industry and his work has been particularly influential in the fields of semiconductor electronics and high performance audio equipment. The list of Dick's impressive professional achievements includes over thirty historic

hobbyists and electronics experimenters of the day. If you built your first transistor radio or audio oscillator with germanium transistors and still remember the many pleasurable hours spent reviewing the latest construction projects from Electronics Illustrated or "Having Fun with Transistors", then Len Buckwalter's substantial contributions to transistor history have been reaffirmed.

audio and electronics publications, a substantial body of audio and electronics patents and ongoing work as a renowned electronics and audio consultant. Dick continues his groundbreaking work in audio electronics with the recent release of Burwen Audio's latest commercial product, the Audio Splendor™ tone control and ambience generation software package.

RALPH GREENBURG

EARLY GERMANIUM TRANSISTOR HISTORY AT MOTOROLA

During a 40 year career with Motorola semiconductors, Ralph Greenburg first became involved with transistor technology during the mid-1950s at a time when hand-made prototype germanium devices were all that was available. He participated in the development of the first transistor applications at Motorola and was an editor and key contributor to several of the highly successful Semiconductor Handbooks published by Motorola in the 1960s and 1970s. Ralph held senior technical and management positions in the Motorola Semiconductor Applications groups and wrote numerous technical publications on early transistor technology. This Oral History provides a truly unique insight into the early days of transistor history and Ralph's ability to communicate in a cogent and entertaining manner ensures you'll enjoy this important account of early semiconductor technology. You'll also read (and hear) the details of the development of the now-standard TO-3 "diamond shaped" power transistor case style, a first for Motorola in 1955 and since used to manufacture billions of devices.

DR. GEORGE LUDWIG

THE FIRST TRANSISTORS IN SPACE

Explorer I, the first U.S. earth satellite, was successfully launched on February 1, 1958 (0348 Greenwich Mean Time) from the Cape Canaveral missile center. The cosmic ray instrumentation package on this satellite was designed by Dr. George Ludwig, who was studying at that time at the University of Iowa in the Cosmic Ray Lab under the guidance of Dr. James Van Allen. The Explorer I instrumentation payload used transistor electronics, consisting of both germanium and silicon devices. This was a very early timeframe in the development of transistor technology, and represents the first documented use of transistors in the U.S. earth satellite program. In this Oral History, Dr. Ludwig provides a very informative and highly readable account of the transistor electronics carried aloft in the Explorer I satellite, and the details of Dr. Ludwig's work with these early semiconductor devices provides a truly unique perspective on these historic events. In addition to the historic use of transistors, the Explorer satellite instrumentation package achieved another major scientific breakthrough – the discovery of the Van Allen radiation belts.

WILF CORRIGAN

MOTOROLA'S PIONEERING 1960s SILICON TRANSISTOR PROGRAM

JACK HAENICHEN

THE DEVELOPMENT OF THE 2N2222

Wilf Corrigan's career in the semiconductor industry has spanned over four decades, beginning in 1960 with his first post-college job as a transistor production engineer at Transitron. During the following 45+ years, Wilf has been a technology innovator and semiconductor industry CEO. He has been directly associated with several of the world's premier transistor and IC companies and his impact on the history of semiconductors has been substantial. This Oral History will highlight Wilf's involvement with the legendary Motorola 1960s silicon transistor program, which was a major milestone in the history of transistor technology.

Since its initial product launch by Motorola at the 1962 IRE Convention, the 2N2222 has become the most widely used and universally recognized transistor of all time. Billions of units have been manufactured over the past 45 years and there is continuing high volume annual production. Whether you are an engineer, experimenter, educator or amateur radio enthusiast, if you have built a transistorized project over the past 45 years, then you have likely encountered the ubiquitous 2N2222, the "universal transistor". This Oral History will highlight the personal recollections of Jack Haenichen, whose pioneering work at Motorola in the early 1960s contributed to the fundamental device and process breakthroughs that were key to the phenomenal success of the 2N2222 and related silicon transistors.

WALTER H. MACWILLIAMS

THE FIRST "WORKING" TRANSISTOR APPLICATION – THE GATING MATRIX

Walter H. MacWilliams enjoyed a distinguished 36 year career with Bell Labs, beginning in 1946 at Murray Hill working on the Mark 65 program, which was a broad-based study of the defense of a combatant ship against a coordinated air attack. It was during this work that Walter began experimenting with the newly invented transistor to determine the suitability of this device as a practical circuit element. His development of the Transistor Gating Matrix in 1949 is credited as being the first working transistor application. You'll discover the details of this unique story and hear Walter's comments about using the first transistors at Bell Labs.

CARL DAVID TODD

THE MAN RESPONSIBLE FOR THE FAMOUS 2N107 TRANSISTOR

Carl David Todd has been involved with transistor engineering since the earliest days of this technology. Carl's first exposure to transistors was in 1949 as a high school student when he built a working point contact transistor. He entered and won a prize in the 1954 Raytheon CK722 Transistor Applications Contest, and was personally involved in the development of the famous 2N107 hobbyist transistor when he worked for GE in the mid-1950s. Read Carl's Oral History for a first-hand account of his historic work with the first transistors.

HOMER COONCE

DEVELOPING TRANSISTOR DIGITAL CIRCUITS FOR THE "FLYABLE TRADIC"

HANNON YOURKE

INVENTING EMITTER COUPLED LOGIC (ECL) TRANSISTOR COMPUTER

COMPUTER AND NIKE ZEUS MISSILES

Homer Coonce joined Bell Labs in 1952, just at the time when the newly invented transistor was made available for research and development. He worked for many years at Bell Labs, developing transistor logic and switching circuits. Most notable was Homer's work on the Flyable TRADIC computer, beginning in 1954. The TRADIC project spanned most of the decade of the 1950s and is credited with establishing the transistor computer as a viable product. In this Oral History, Homer recounts his work on two historic Bell Labs/Western Electric transistor computer applications – Flyable TRADIC and the Nike Zeus missile system.

CIRCUITS AT IBM IN THE 1950s

Hannon S. Yourke's 30 year career with IBM began in 1955 when he joined the newly formed transistor circuits group in Poughkeepsie. All IBM computers at the time were vacuum tube based, and the transistor group had been formed to investigate and develop the potential for transistors in future IBM products. He filed for patent 2,964,652 (Transistor Switching Circuits) in Nov 1956. This circuitry developed by Mr. Yourke was known initially as current steering logic, but was later called emitter coupled logic, or ECL, and became the dominant circuitry for all high speed computer logic throughout the 1960s, 1970s and 1980s.

JERRY HERZOG

DEVELOPING THE FIRST TRANSISTOR IN 1952 AND THE LEGENDARY 1970s 1802 MCROPROCESSOR

Jerry Herzog's 30 year career in semiconductors began at RCA Labs in 1951, where he developed some of the first applications for the newly emerging transistor technology. One of Jerry's most important contributions to transistor development was his pioneering work on the first completely transistorized television receiver - this unique device was developed at the RCA Labs in 1952 and represents a major milestone in transistor history - this TV set is currently on display at the Smithsonian. A separate section has been included at the end of his Oral History to document this important early TV work. Jerry provides personal and technical commentary about this historic project, as well as other important contributions, including the 1802 microprocessor, in this Oral History.

H. C. LIN

STARTING AT RCA IN 1950 AND INVENTING THE QUASI COMPLEMENTARY TRANSISTOR AMP

Dr. Hung Chang Lin has been associated with the semiconductor field for over 50 years, beginning in 1950 with his pioneering work at the RCA ISL labs with early transistor circuitry. H.C. Lin is the holder of 57 U.S. patents, and is the author/co-author of 170 technical papers and several respected texts on semiconductors, including "Integrated Electronics," (Holden Day, 1967), "Selected Semiconductor Circuits Handbook," (Wiley and Sons, 1960), and "Semiconductor Electronics Education Committee Notes 1," (Wiley and Sons, 1963). In the 1950s and 1960s, he worked at several key semiconductor companies, including RCA, CBS/Hytron and Westinghouse. He was elected an IEEE Fellow "for contributions to semiconductor electronics and circuits and pioneering of integrated circuits".

PAUL PENFIELD JR.

HANS CAMENZIND

PROLIFIC AUTHOR OF OVER 70 CLASSIC ARTICLES ON 1950s TRANSISTOR TECHNOLOGY

Professor Paul Penfield Jr. was one of the first and most prolific authors of articles on the just emerging transistor technology of the 1950s. These classic articles were published in such widely read electronics magazines of the day as Radio-TV News, Radio-Electronics, Audio and Audiocraft. If you were an electronics experimenter, engineer, or hobbyist in the 1950s, and were eager to learn about transistors and actually build a construction project using these newly invented devices, it's likely you read one of Paul's pioneering articles. Beginning in 1954, and continuing through 1958, Paul had more than 70 articles on transistors published in electronics industry publications. This four year period represented a rapidly changing time in transistor technology, and Paul's well written articles provided a readable and interesting account of these developments.

STARTING AT RCA IN 1950 AND INVENTING THE QUASI COMPLEMENTARY TRANSISTOR AMP

The type 555 Integrated Circuit, produced initially by Signetics in 1972, is the most successful IC yet designed, with billions of units manufactured by multiple semiconductor companies over the past 30 years. Hans Camenzind is the designer of this historic IC, and his Oral History offers real insight into the original 555 design and development process. In addition, Hans continues to be active as an analog IC designer and his comments on the changes in the IC design process since the 1970s are very informative and uniquely reflect the incredible amount of change that the semiconductor industry has seen.

JERRY SURAN

THE INVENTION OF THE UNIJUNCTION TRANSISTOR AT THE GE ELECTRONICS LAB IN THE 1950s

Originally known as the "double-base diode", the unijunction transistor was invented at the General Electric Electronics Lab in Syracuse in the early 1950s. This unique, single "pn" junction device became a very big seller for GE in the late 1950s and into the 1960s. In this new Oral History, Professor Jerry Suran provides a first-hand account of his pioneering work over 50 years ago with the development of the first unijunction transistor devices and applications.

ART UHLIR JR.

INVENTING THE VARACTOR DIODE AT BELL LABS AND PIONEERING WORK WITH POROUS SILICON

Art Uhlir Jr was responsible for the development of the varactor diode at Bell Labs in the 1950s. Over the past 50 years, this invention has become a major component of the semiconductor industry. In this Oral History, Art describes his work with these diodes, as well as discussing the early days of transistor technology. Art also highlights his pioneering work with porous silicon, which was conducted at Bell Labs in the 1950s, working along with his wife, Inge.

DWIGHT JONES

DEVELOPING EARLY TRANSISTOR AUDIO CIRCUITS AND CONTRIBUTING TO THE GE TRANSISTOR MANUALS

Dwight V. Jones was employed at General Electric for forty years, from 1947 to 1987. He started at the beginning of the GE's transistor efforts and was involved with semiconductors for most of his career. Dwight is the author of numerous technical papers, holds several patents, and may be best known to transistor engineers as a major contributor to the highly regarded series of "Transistor Manuals" developed by General Electric in the 1950s and 1960s. His many contributions to early semiconductor applications include transistor audio, test equipment, and SCR motor controls.

SANFORD BARNES

STARTING AT HUGHES AIRCRAFT IN 1951 AND WORKING WITH HARPER NORTH ON EARLY TRANSISTORS

Sanford (Sandy) Barnes has been active in transistor technology for over 50 years, starting as a young engineer in 1951 with the assignment of producing "hand-made" germanium point contact transistors at Hughes Aircraft. He has held numerous research and senior management positions with several key companies involved with semiconductor development, including Hughes Aircraft, Pacific Semiconductors Inc, and TRW. Sandy was very active in semiconductor research in the 1950s and 1960s and was granted multiple patents in transistor and diode technology.

GENE WECKLER

WORKING AT SHOCKLEY TRANSISTOR CORPORATION IN 1958 AND DEVELOPING APPLICATIONS FOR SHOCKLEY TRANSISTOR DIODES

Gene P. Weckler has been active in semiconductor technology since the late 1950s, with a career that has taken him to such industry pioneering companies as Shockley Transistor Corporation, Fairchild Semiconductor, and EG&G Reticon. His first major work assignment after graduating with a BSEE from Utah State University in 1958 was as an Applications Engineer at Shockley Transistor Corporation, the historic company credited by many as the first semiconductor company in Silicon Valley.

NEVILLE FLETCHER

DEVELOPING THE FIRST 1950s GERMANIUM POWER TRANSISTORS

Neville Fletcher has been active in multiple areas of physics for over 50 years. Professor Fletcher is a Fellow of the Australian Academy of Science and of the Australian Academy of Technological Sciences and Engineering. He has published five books and over 170 papers. His important contributions to the development of germanium power transistor technology were made in the 1950s, when he was working for an early pioneering transistor company (Transistor Products Inc). TPI was purchased by Clevite in the mid-1950s, and became a large-scale producer of germanium power transistors.

ADOLPH BLICHER

JOINING RCA IN 1955 AND DEVELOPING THE CLASSIC 2N301 AND 2N404 GERMANIUM TRANSISTORS

BOB MENDELSON

WORKING AT RCA ON EARLY TRANSISTORSR, ICs AND THE HISTORIC NUVISTOR TUBES

Joining Radio Receptor's Germanium Research Department in 1954, Adolph Blicher's first assignment was to develop high speed PNP germanium transistors that could be used in computers and radio receivers. At this time, most available transistors had performance suitable only for low frequency applications such as hearing aids. DR. Blicher succeeded in developing RR's first computer transistor the RR156. In 1955, he began work at RCA and was responsible for the development of a number of successful transistors types including the 2N301 and the 2N404. His later work at RCA resulted in the development of a series of germanium and silicon transistors with ever-increasing high frequency and high speed switching response characteristics.

Bob Mendelson joined RCA in 1953 with an MS degree in Chemical Engineering. He spent the next six years in the Methods and Process Lab (M&P Lab), responsible for the hydrogen furnaces, electroplating, and all chemical problems. He fully retired from RCA in 1989. During those 36 years, Bob had the unique opportunity to work with several key RCA technologies, including germanium transistors, silicon transistors, integrated circuits and Nuvistors. He has authored numerous books and articles (including two highly regarded 1960s articles on Nuvistors in the RCA Ham News publication), and continues today an active ham radio operator (W2OKO). Bob has been issued two U.S. patents.

MAC MACBRIDE

BUILDING THE FIRST TI TRANSISTORS WITH HAND-ASSEMBLY AND WATCHMAKERS TOOLS

D. D. "Mac" McBride worked at Texas Instruments from July 1953 until early retirement in April 1975. This 20+ year career spanned the critical early years in transistor technology and his Oral History provides insight into the tremendous changes that occurred during this time. It is interesting to note that Mr. McBride's first assignment at TI was that of assembler of point contact transistors, and that his earlier training as a watchmaker provided the essential skills for this job. As you'll discover, the performance of these early transistors was quite unpredictable and largely dependent on the precise mechanical placement and adjustment of sharpened electrodes that held in place with glue!

MARY ANNE POTTER

WORKING AT TEXAS INSTRUMENTS IN THE EARLY 1960s ON EARLY ICs USED IN THE MINUTEMAN MISSILE SYSTEM

Mary Anne Potter started to work at Texas Instruments on June 26, 1962, as a process/product engineer on Minuteman ICs. Early on, she became the lead process engineer for the quad-diffused IC designs at TI, and was involved in some of the original and historic work on the first large scale production of integrated circuits. Ms. Potter stayed at TI through the 1960s, working with a variety of integrated circuit development activities. Later, she was employed at a number of other well known semiconductor companies, such as MOSTEK, AMI, and Fairchild. Ms. Potter later returned to TI, where she became TI's first female fab manager.

HISTORIC TRANSISTOR COMPANIES

During the 1950s and 1960s, there were a handful of companies that made major contributions to the development of the transistor. Use the links below to visit Transistor Museum exhibits constructed to document these historic activities. You'll find Oral Histories from many of the scientists and engineers who implemented these important early transistor programs. You'll also find detailed information regarding early transistor literature and descriptions of the major semiconductor advances made at these companies.

USE THESE LINKS TO FIND DOZENS OF ADDITIONAL ORAL HISTORIES FROM PIONEERS IN TRANSISTOR DEVELOPMENT.

GENERAL ELECTRIC
RCA
TEXAS INSTRUMENTS

COMING SOON

Fairchild
National Union
Radio Receptor
Raytheon
Shockley Transistor
Western Electric

TRANSISTOR MUSEUM PHOTO GALLERY

PHOTOGALLERY

The Museum's most popular exhibit. Here you'll find photographs and descriptions of unique and historic devices or applications relating to the semiconductor history from the last century. Visit this exhibit to confirm identity of devices you have found or just spend a rainy afternoon browsing the exhibits. The Transistor Museum™ Photo Gallery has been established to provide an easily accessible and informative repository of high quality photographs and detailed information about many of the unique and historic transistors, diodes and integrated circuits from the early days of this exciting technology. This material should be an invaluable aid to historians, experimenters, hobbyists and anyone else interested in learning about the

history of semiconductors and how these ubiquitous devices have come to shape the modern world.

OVER 60 HISTORIC DEVICES SHOWN. CHECK BACK OFTEN AS WE ARE PLANNING A MAJOR UPDATE TO THIS EXHIBIT.

BELOW ARE LINKS OF SOME RECENT ADDITIONS TO THE GALLERY.

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LINK TO TI 2N335

When Explorer 1, the first U.S. earth satellite, was launched in February 1958, it carried aloft radiation detection circuitry designed by Dr. George Ludwig – he used the newly released TI 2N335 silicon grown junction transistor type for this unique and demanding application.

TEXAS INSTRUMENTS R212 (Polaris Missile Transistor)

One of the first documented large scale military uses of transistors was the Polaris missile program, which was initiated in 1956. The initial versions of guidance computer used discrete transistor components, such as the R212. This high reliability germanium device was supplied to the Polaris program by TI throughout the 1960s.

2N27 2N29 2N110

Learn about the first commercial transistors manufactured by Western Electric in the 1950s. These are historic devices and represent an important aspect of early transistor history.

LINK TO MOTOROLA 2N705

Although germanium transistor technology was largely replaced by silicon in the 1960s, the diffused base germanium mesa type, developed in the late 1950s, was one of the best high frequency performers for many years. Motorola and TI were the leaders in this technology – the Motorola 2N705 was one of the most commercially successful devices of this type.

TRANSISTOR MUSEUM STORE
MUSEUMSTORE

The Transistor Museum™ Store has been established to provide an easily accessible (and reasonably priced) source of unique and historic transistors, diodes and integrated circuits from the early days of this exciting technology. Use the Museum Store link to explore what's available and to compare the different types. In each case, you'll find a link which will take you to more details about the specific Museum offering and how to purchase.

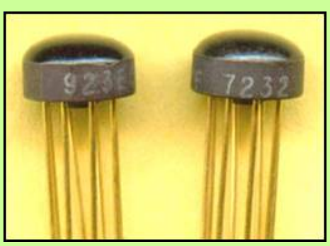
To aid historians, experimenters, hobbyists and anyone else interested in learning about transistors, each Transistor Museum™ device is supplied with historical information, circuits and photos.

The Museum Store will soon be expanding as we add many more unique and historically important semiconductors of all types. In addition, every device that you purchase will now include a Transistor Museum™ Historic Semiconductor Fact Sheet, which is a full page-sized document containing a collection of useful facts, pictures and commentary about the specific device. You won't find anything like this elsewhere, and you'll likely spend many rewarding hours reviewing this unique material and learning about semiconductor history.

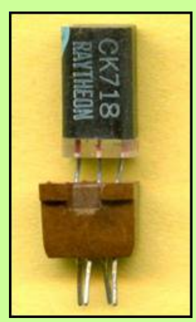
LISTED BELOW ARE EXAMPLES OF HISTORIC DEVICES AVAILABLE AT THE TRANSISTOR MUSEUM STORE.

Historic Western Electric 2N110
Point Contact Transistor
Vintage 1950s – 1960s
Experiment with the
First Transistor Technology.

GE 2N43 2N44 2N45 Germanium
PNP Alloy Junction Transistor
General Electric Classic "Top- Hat" Styles
from the 1950s & 1960s.



Fairchild uLogic® 923
RTL Integrated Circuit
J-K Flip-Flop
One of the First ICs Available. Used Extensively in Digital Logic.



Raytheon CK718
Hearing Aid Transistor
From the Early 1950s. The First Transistor in Volume Production.

HISTORIC TRANSISTOR CONSTRUCTION PROJECTS

USING THE FIRST TRANSISTOR TYPE, GERRY FRITON HAS DEVELOPED A MODERN POINT CONTACT TRANSISTOR CIRCUIT – AN AUDIO AMPLIFIER USING 60 YEAR OLD 2N23 TRANSISTORS. YOU'LL ENJOY THE CONSTRUCTION DETAILS OF THIS UNIQUE PROJECT.
POINT CONTACT TRANSISTOR AUDIO OSCILLATOR

THE AUGUST 1956 EDITION OF RADIO AND TV NEWS PUBLISHED A CLASSIC TRANSISTOR CONSTRUCTION PROJECT BY PAUL PENFIELD JR. THIS TRANSISTOR MUSEUM CONSTRUCTION PROJECT IS BASED ON PAUL'S ORIGINAL MID-CENTURY TRANSISTOR DESIGN.
A CLASSIC 1956 PAUL PENFIELD JR. GERMANIUM TRANSISTOR AMPLIFIER IS RECONCONSTRUCTED BY THE TRANSISTOR MUSEUM

THE VALANDY COMPANY INTRODUCED ONE OF THE FIRST COMMERCIAL TRANSISTOR CONSTRUCTION KITS IN THE 1950s – A CODE PRACTICE OSCULLATOR USING SURPLUS RAYTHEON HEARING AID TRANSISTORS. YOU CAN BUILD AN ORIGINAL WITH THIS MUSEUM LINK.
A CLASSIC 1950s TRANSISTOR KIT – THE VALANDY CODE OSCILLATOR

FAIRCHILD'S uLOGIC ICs WERE INTRODUCED IN THE EARLY 1960s AND WERE THE FIRST ICs GENRALLY AVAILABLE TO THE PUBLIC. BILL JONES HAS RECONSTRUCTED A CLASSIC HAM RADIO "KEYER" ORIGINALLY DESCRIBED IN A 1967 QST MAGAZINE.
BILL JONES (K8CU) - MICRO "TO" KEYER REVISITED

NED ELY USES 1950s BLUE CK722 TRANSISTORS FOUND IN A BOX FROM HIS CHILDHOOD AND MODERN BLUE LEDs TO BUILD A SPECTACULAR FLASHING LIGHT MULTVIBRATOR.
BLUE CK722s AND BLUE LEDs COMBINE FOR A BLUE "BLINKER"

ANNOUNCED IN EARLY 1953, THE RAYTHEON CK722 WAS THE FIRST TRANSISTOR AVAILBLE TO THE GENERAL PUBLIC. THIS RADIO PROJECT WAS CREATED IN 2003 TO COMMEMORATE THE 50th ANNIVERSARY OF THIS HISTORIC AND WELL REMEMBERED DEVICE.
BUILD THE 50th ANNIVERSARY CK722 TRANSISTOR RADIO

LEARNING ABOUT TRANSISTORS RECOMMENDED BOOKS AND ARTICLES AND INFORMATIVE SITES

SOME INTERESTING TRANSISTOR FACTS

1. The first transistor type, called point contact, was invented at Bell Labs in December 1947 by John Bardeen and Walter Brattain.

2. The invention of the transistor was made public in June 1948 at a press conference held by Bell Labs in New York City.

3. The second transistor type, called grown junction, was developed at Bell Labs in 1950, based on the theoretical work of William Shockley. The Nobel Prize in Physics 1956 was awarded jointly to William Shockley, John Bardeen and Walter Brattain *"for their researches on semiconductors and their discovery of the transistor effect."*

4. Other early 1950s commercial transistor types included the surface barrier and the alloy junction. All these early commercial transistor types were constructed from germanium.

5. Raytheon announced the CK722 in January 1953. This was the first transistor generally available to the public. Raytheon led all other manufacturers in volume production of transistors, and commemorated its "Millionth Transistor" on June 23, 1954.

6. Other semiconductor manufacturers began high volume production of germanium transistors in the mid-1950s. Major companies included General Electric, Motorola, Philco, RCA, Sylvania, Texas Instruments and Western Electric.

7. Texas Instruments announced the 900 series of transistors in late 1954. These were the first silicon transistors available commercially.

8. Total 1955 production of all transistors was 3,500,000 units, and all but a few were germanium.

9. Additional germanium and silicon transistor types were developed in the late 1950s, including the diffused base/mesa.

10. In January 1960, Fairchild announced the silicon planar transistor technology with the 2N1613 device. This technology was rapidly adopted by most other transistor manufacturers and has become the standard structure for modern semiconductor devices. The planar process was also an important technology for the

commercial development of ICs, which appeared on the market in this same timeframe.

11. In the early 1960s, Texas Instruments and Fairchild announced the first integrated circuits. These first ICs contained several transistors and related components on a single chip.

12. Following the lead of TI and Fairchild, other semiconductor manufacturers soon began commercial production of integrated circuits, including established transistor companies such as Sylvania, Motorola, GE, RCA, and Transitron, as well as newly formed companies such as Signetics and Siliconix.

13. The 1960s saw widespread use of the new IC technology in military, industrial and consumer electronics; both digital and analog IC types were produced in very large quantities.

14. The level of IC integration (the number of transistors contained on a single integrated circuit) increased substantially in the 1960s, with hundreds transistors per chip by the late 1960s.

15. Gordon Moore (co-founder of Fairchild and Intel) authored an article in the April 1965 issue in *Electronics* magazine, predicting the continued rapid increase in the level of integration for ICs. This has become known as "Moore's Law" and describes the doubling of the number of transistors per IC approximately every two years.

16. The first Intel microprocessor, the 4004, was released in Nov 1971 and contained 2300 transistors. Other more complex microprocessor types soon followed. For example, the 1979 Intel 8088, used in the first IBM PC, contained 29,000 transistors.

17. The level of integration continued to expand with the introduction of ever more powerful ICs, including microprocessors. The first Intel Pentium microprocessor was introduced in March 1993 and contained over 3,000,000 transistors. At this level of integration, a single microprocessor chip contained almost as many transistors as were produced in total in 1955 (see item #8 above).

18. In a February 13th 2003 Wall Street Journal article, Gordon Moore summarized the status at that time of the continued increase in the level of integration as follows:

- "The current number of transistors the (semiconductor) industry churns out each year is 10 to the 18th power, or 1,000,000,000,000,000,000, a figure sometimes expressed as one quintillion."

- "Consumers typically can buy 50 million transistors for a dollar on some memory chips. It really is a spectacular industry".

19. Current microprocessors such as the Apple A8 used in the iPhone 6 contain over 2 billion transistors.

20. The [April 2015 IEEE Spectrum magazine] featured several articles published to commemorate the 50th anniversary of Moore's Law. In this issue, Dan Hutcheson's article "Transistors, by the Numbers", quantifies the current state of transistor production with this statement "In 2014, semiconductor production facilities made some 250 billion billion (250×10^{18}) transistors. This was, literally, production on an astronomical scale. Every second of that year, on average, 8 trillion transistors were

produced. That figure is about 25 times the number of stars in the Milky Way and some 75 times the number of galaxies in the known universe."

RECOMMENDED BOOKS AND ARTICLES

"HISTORY OF SEMICONDUCTOR ENGINEERING" by Bo Lojek.
Dr. Lojek's recently published book is a "Must-Read" for anyone interested in the history of semiconductors. Beginning with a detailed view of the seminal Bell Labs semiconductor research activities in the 1940s, Bo provides a compelling account of the important events and discoveries that shaped semiconductor progress over the ensuing three decades. In addition, this book provides an extensive and well-researched roster of many of the key contributors to semiconductor history.

"CRYSTAL FIRE" by Michael Riordon and Lillian Hoddeson.
***Crystal Fire* is the definitive text on the history of semiconductors, and specifically on the events, technology and people who have been responsible for "The Invention of the Transistor and the Birth of the Information Age". The authors had unprecedented access to the early transistor records at Bell Labs and provide detailed information on the key events leading up to the discovery of the transistor in 1947. Other key topics covered are the invention of the integrated circuit and the beginnings of Silicon Valley.**

"TI, THE TRANSISTOR AND ME" by Ed Millis
Mr. Ed Millis is uniquely qualified to comment on the early history of the transistor at Texas Instruments. After joining Geophysical Service, Inc., predecessor of Texas Instruments, in 1950 as an engineer on military electronic equipment, Ed transferred in June 1954 to the Semiconductor organization. This was the beginning of a decade's long and successful association between Ed and TI semiconductors. In his new book, Ed has created a very readable, detailed account of the technically challenging and personally rewarding years he spent at TI.

"INSTRUMENTS OF AMPLIFICATION" by Pete Friedrichs.
Pete Friedrichs is a modern day semiconductor Renaissance Man. His most recent book, "Instruments Of Amplification – Fun with Homemade Tubes, Transistors and More" provides a very enjoyable account (with excellent "hands-on" instructions) for those who want the satisfaction of constructing their own transistor. Yes, that's right – detailed instructions for building either a point contact or junction transistor! Definitely worth a visit. See Pete's homepage for information on his other work.

"THE IRRESISTABLE TRANSISTOR" by Harry Goldstein.
Article from the March 2003 IEEE Spectrum magazine.
Harry Goldstein, the Editorial Director of IEEE Spectrum magazine, visited Raytheon's Norm Krim in 2003 and learned first-hand the memorable details of the development of the first transistor available to the general public, the CK722. This germanium alloy junction transistor was introduced in early 1953 and had an immediate and long-lasting impact on the careers of the young experimenters and engineers who would later make major contributions to the semiconductor industry.

"THE LOST HISTORY OF THE TRANSISTOR" by Michael Riordan.
Article posted April 30, 2004 at online IEEE Spectrum magazine.
In this article, Michael Riordan, co-author of the classic and highly regarded text on semiconductor history, *Crystal Fire*, recounts the history of the silicon transistor, beginning with the dramatic announcement by Texas Instruments at the May 1954 Radio Engineers (IRE) National Conference on Airborne Electronics, of the availability of the first commercial silicon transistors. Riordan's article additionally describes the lesser-publicized work at Bell Labs during this same timeframe that had simultaneously resulted in the development of the first silicon transistors.

INFORMATIVE SITES

MARK PD BURGESS - TRANSISTOR HISTORY

Mark's site, developed to document Transistor History, is an excellent resource on this topic. He has conducted detailed and original research on a number of important transistor types and early companies and, importantly, this work is presented in a very readable style. Mark's website is a "must-visit" for those interested in transistor history.

COMPUTER HISTORY MUSEUM

If you travel to the Bay Area, you should make every effort to visit the Computer History Museum in Mountain View, Ca – the Heart of Silicon Valley. In addition, the website maintained by this world class museum is an unparalleled resource for those interested in early transistor history. You can spend many hours viewing the important historical material available on this site.

JAMES MCGONIGAL – FLICKR PHOTO ALBUM

James McGonigal has developed an extensive Flickr photo album of early semiconductors. The photography is superb and Jim's commentary adds historical context for the many devices shown. This site is definitely worth a visit.

KIRT BLATTENBERGER - RF CAFE

Kirt has created the premier website for electrical engineers. There is a wealth of engineering related material and hundreds of useful links. This site is a real asset to electrical engineering technology. You'll also find links to many interesting historical articles and museums related to early semiconductors.

ANDREW WYLIE – MR. TRANSISTOR

Andrew's website on early transistor devices and history is without a doubt the best known and widely visited site on this topic. Andrew ("Mr. Transistor") continues to be a pioneer in documenting early transistors and continues to expand his website.

DON PIES – REGENCY TR1 TRANSISTOR RADIO HISTORY

Don has created a wonderful website with definitive information on the Regency TR-1 radio, which was the first all-transistor radio sold commercially. This radio was a major milestone in transistor history. Great links, photos and commentary.

STEVE REYER – WORLD'S FIRST POCKET RADIO

Another phenomenal site for the first commercial transistor radio, the Regency TR1. Steve has been actively documenting the TR1 for many years and his excellent work has been recognized internationally.

MASAHIRO NAKAHORI – COLLECTION OF SEMICONDUCTORS

Masahiro has created an unparalleled photographic display of early transistor types, including devices from Japan, Europe, Russia and the U.S. This is a "must-visit" site for semiconductor collectors.

RADIOMUSEUM.ORG

This remarkable site has continued to expand over the past few years and has become a major resource for those interested in early semiconductor history. A unique and very important feature is the search for a specific transistor type/part number for info on a broad range of historic transistors. You'll also find excellent research papers on this topic.

PBS TRANSISTOR HISTORY

Lots of research and links. This site is one of the most comprehensive commercial sites on this topic, with a very broad range of coverage and links to other sites. Much information on the invention of the transistor.

BELL SYSTEM MEMORIAL – HISTORY OF THE TRANSISTOR
Terrific site dedicated to Bell System history, including transistors. Contains many excellent photos of Bell Lab's early work with transistors.

JAN DE GROOT – VINTAGE TRANSISTORS
Jan has developed a large and expanding website that is a very worthwhile resource for those interested in early transistor history. You'll find many detailed photos and comprehensive coverage of early transistor companies.

DIY CALCULATOR
Clive (Max) Maxfield and Alvin Brown have developed one of the "coolest" technology sites around. The sections on early electronic calculator/computer history provide good coverage of transistors. This is a great site!

ALAN KASTNER - RADIOWALLAH
Alan has created a terrific site, which features fine photography and detailed technical specs of many early transistor radios, primarily of Japanese manufacture. A unique feature is Alan's "See the Insides" of each radio, which provides photos of the actual transistors used in these radios.

CURATOR'S UPDATE AND CONTACTING THE MUSEUM

With this May 2015 update and re-organization of the Museum homepage, we have reviewed and confirmed all links. Some of the material here was first developed and placed on the web in 2001, and that's ancient history given the changes with internet technology over the past decade. If you find a link that no longer works, and have a resulting comment or question regarding a specific transistor history topic, just let us know and we'll do our best to respond. Also, we haven't been able to keep up with all the emails from museum visitors - please accept our apologies and know that the museum continues to grow and we have plans for a greatly expanded site in the future.

Please email your comments directly to Jack Ward, the Museum Curator, at: transistormuseum@aol.com

Finally, I want to thank all the Transistor Museum visitors who have taken the time to email me with positive and supportive comments about this site. With over 100,000 visits a year, the Transistor Museum continues to provide

a unique and frequently referenced repository of historical information and personal reflections that likely would not otherwise be available. Please email us if you'd like to donate historic devices or documentation, or just want to discuss early transistor history.

http://www.transistormuseum.com

AWSH.ORG

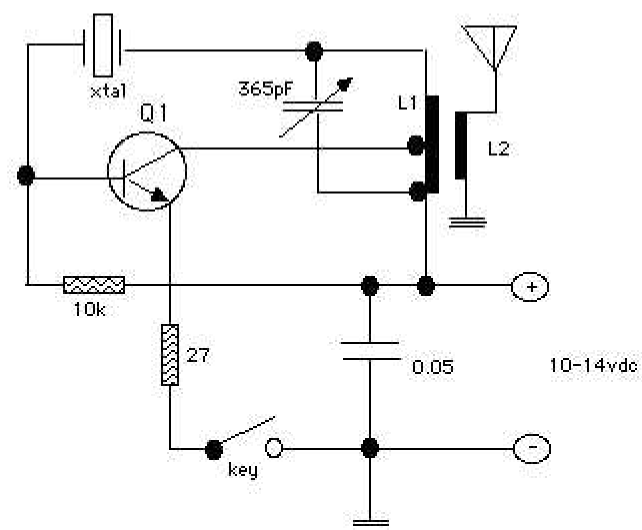
stuff that i do and things that i make

michigan mighty mite

PUBLISHED SEPTEMBER 12, 2016

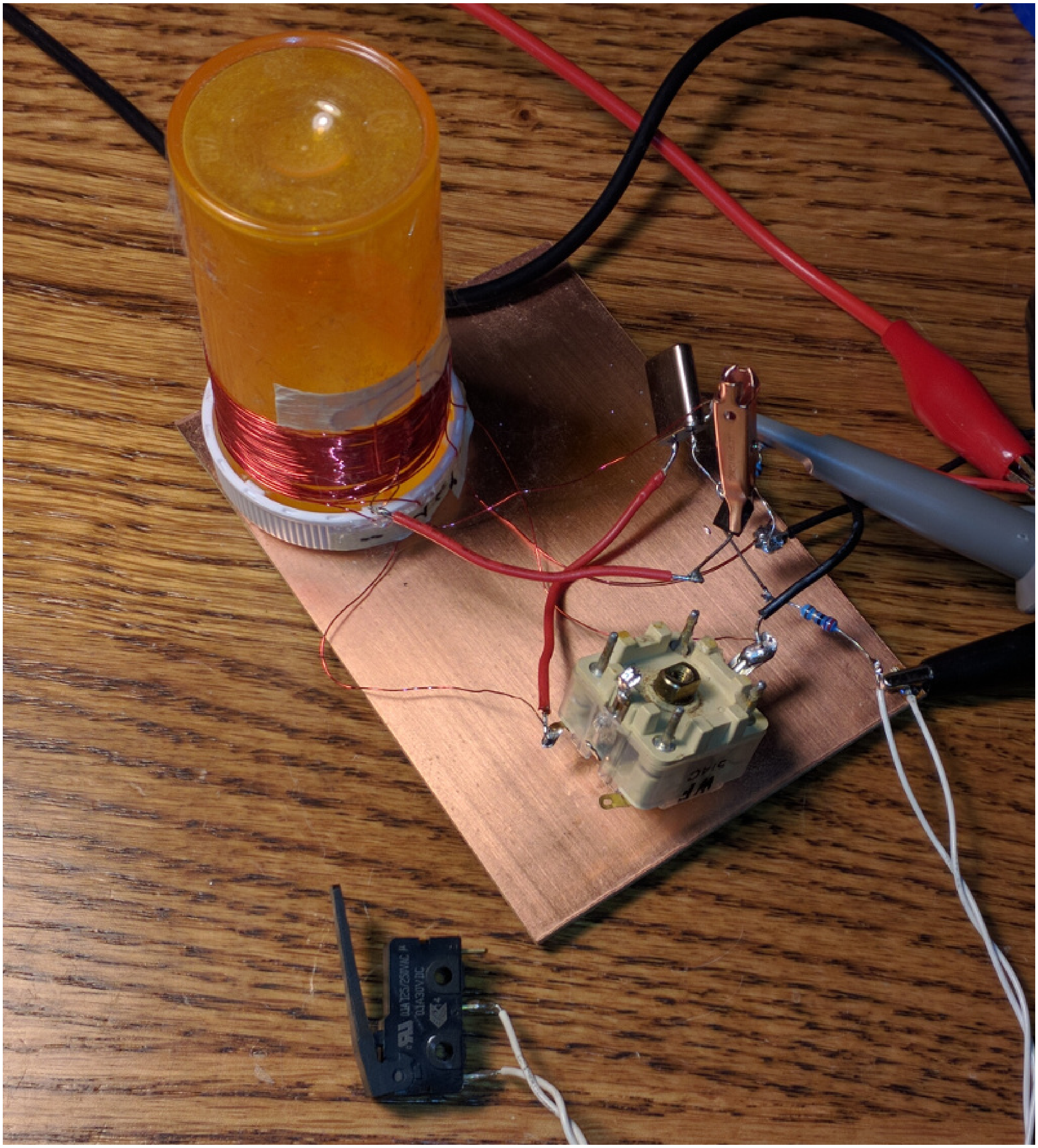
I've been listening to some of the older episodes of the soldersmoke podcast, and figured I'd put together one of the michigan mighty mite transmitters that they've mentioned so often. I even had a 3.579 colorburst crystal in the junk box.

The michigan mighty mite is a very simple 7 component transmitter that is easy to build. It is a great first project for someone getting into homebrewing.



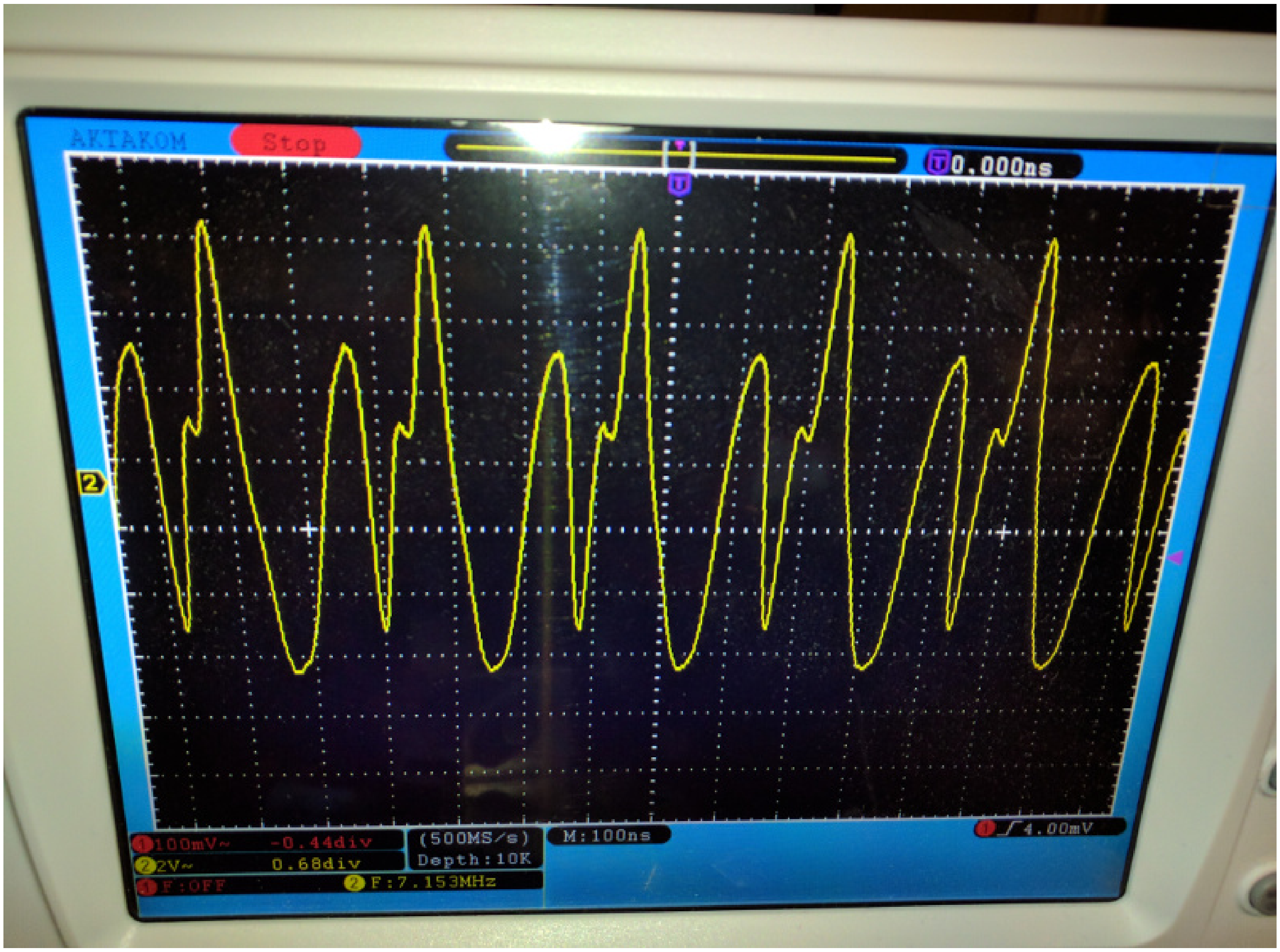
The schematics and more detailed instructions can be found here.

Here is my version.

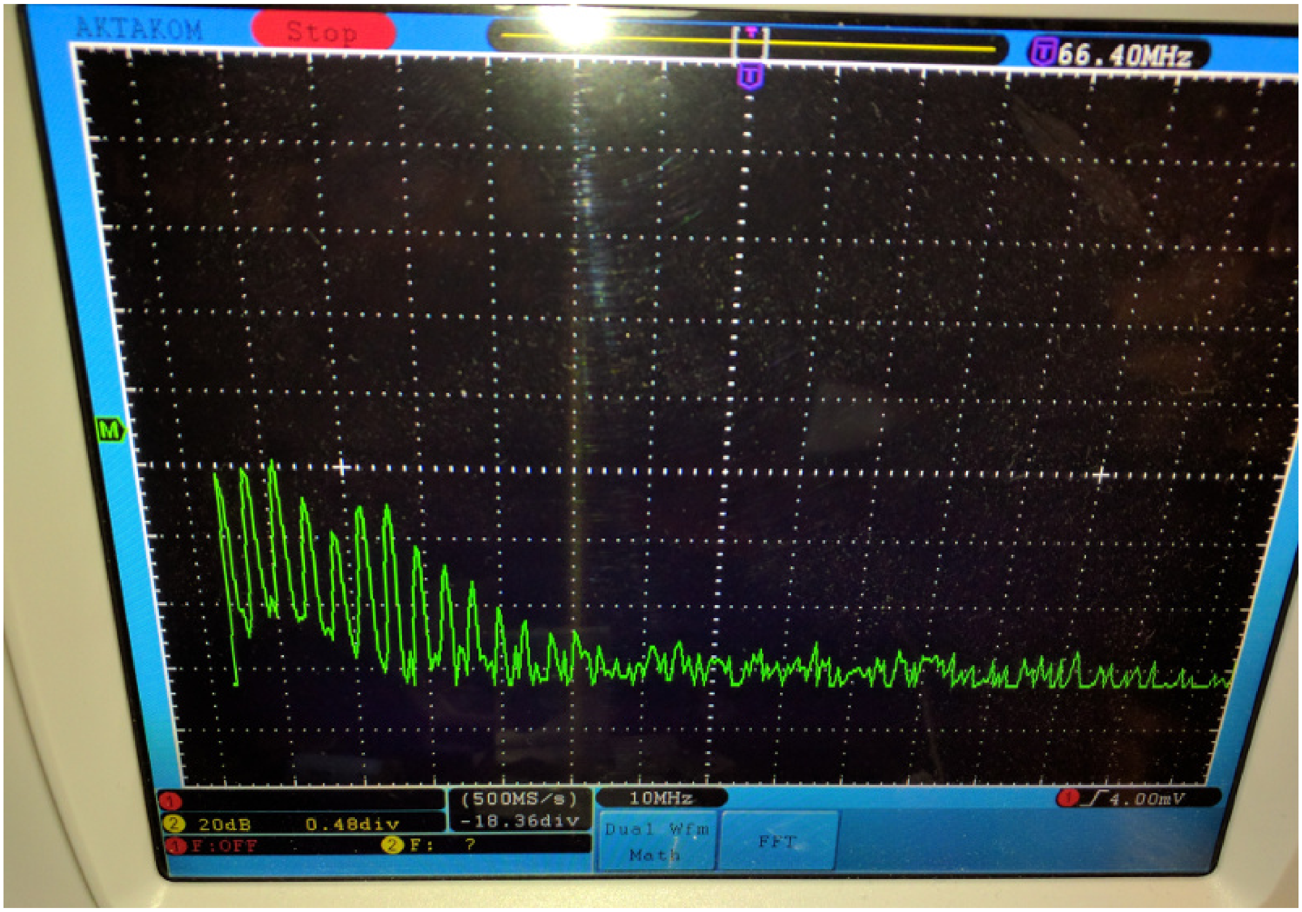


I wound the coil on a pill bottle and used a polyvaricon from an old am radio. It is using a 2n2222 transistor and a 3.579 crystal. The switch is used as the key.

As you can see in the following wave form, this little transmitter really needs a filter before using it on the air. The scope's frequency counter is even reading the second harmonic of 7.15MHz instead of 3.579MHz.



Looking at the FFT, you can clearly see the harmonics in the signal.



If you build this transmitter, make sure to add a low pass filter before attempting to use it on the air.

PUBLISHED IN **CIRCUITS**, **ELECTRONICS** AND **RADIO**

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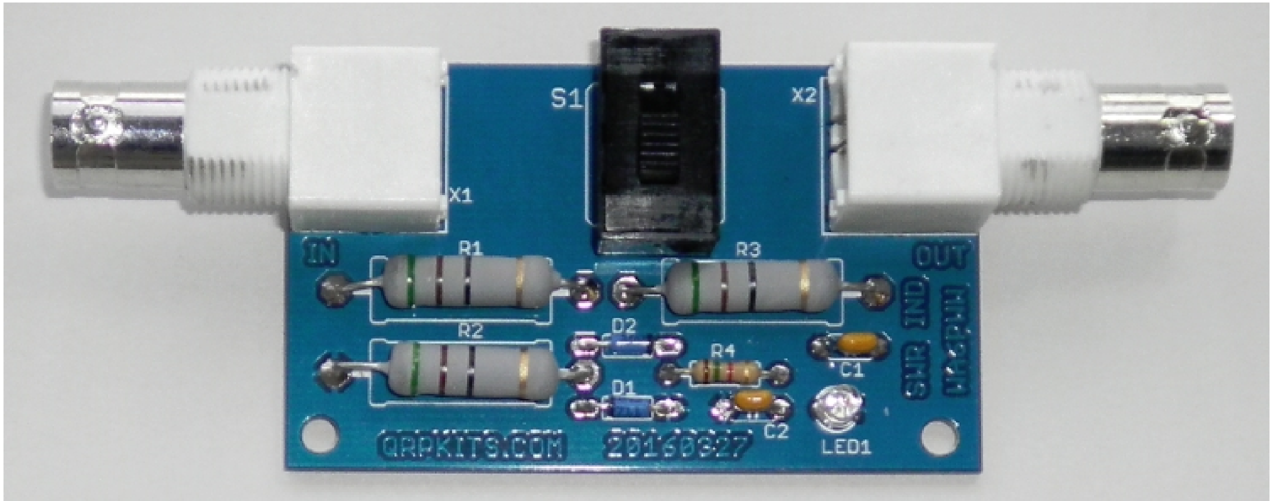
Pacific Antenna Easy SWR Indicator Kit



Description

Monitoring the match of an antenna to your transmitter or adjusting an antenna tuner for best match requires an indicator of the reflected power as an indication of how well the antenna is matched to the transmitter.

Displays reflected power level through the brightness of an LED.

Using this bridge, the antenna or tuner are adjusted for the minimum LED brightness and in most cases, the LED will completely extinguish.

The resistive bridge limits the mismatch seen by the transmitter and protects your transmitter from seeing high SWR.

A very easy kit to assemble and does not require winding any toroids or any adjustments.

Recommended it as a great kit for new or returning builders.

Specifications

Recommended for power levels of 0.2 to 5 watts
Works from 160M to 6M
Provides protection for transmitter by limiting reflected power during tuneup
Indicates match to antenna by dimming or extinguishing of LED
Constructed on a 1.5x 2.5 inch printed circuit board
Includes board mounted BNC connectors.

Support

PACIFIC ANTENNA
QRP KITS.COM
qrpkits.com@gmail.com

Tools Needed

- Temperature Controlled Soldering Station with small tip or 15-35 watt soldering iron with small tip.
- Solder 60/40 or 63/37 Tin-Lead
- Small Diagonal Cutters
- Small Needle Nose Pliers
- Pencil, Pen, and/or Highlighter
- BRIGHT work light

Optional

- Magnifying headpiece or lighted magnifying glass.
- Multi-meter
- Solder Sucker or Solder Wick
- Small multi-blade Screw Driver
- Knife or Wire Stripper
- Small Ruler
- Cookie Sheet to build in and keep parts from jumping onto the floor.

Construction Techniques

- Please take time to inventory the parts before starting and report any shortages to QRPKITS.com

- Pre-sorting the resistors and capacitors can speed up the assembly and reduce mistakes.

- You can insert several parts at a time onto the board. When you insert a part bend the leads over

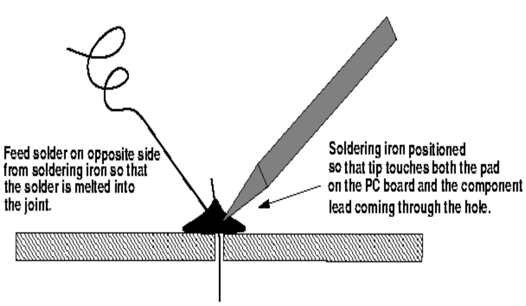
- slightly to hold the part in place, then solder all at the same time. Clip the leads flush.

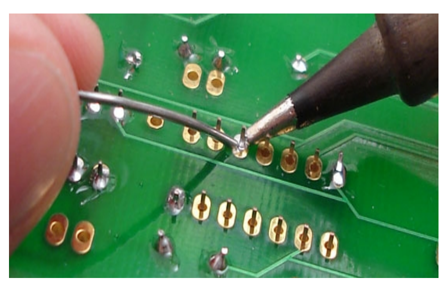
- Most parts should be mounted as close to the board as possible.

- It is best to use a Temperature Controlled Soldering Station with small tip or a 15-35 watt soldering iron with small tip. Conical or very small screw driver tips are best.

- If you are a beginner, new to soldering, there are a number of resources on the web to help you get on the right track soldering like a pro. Google Soldering Techniques.

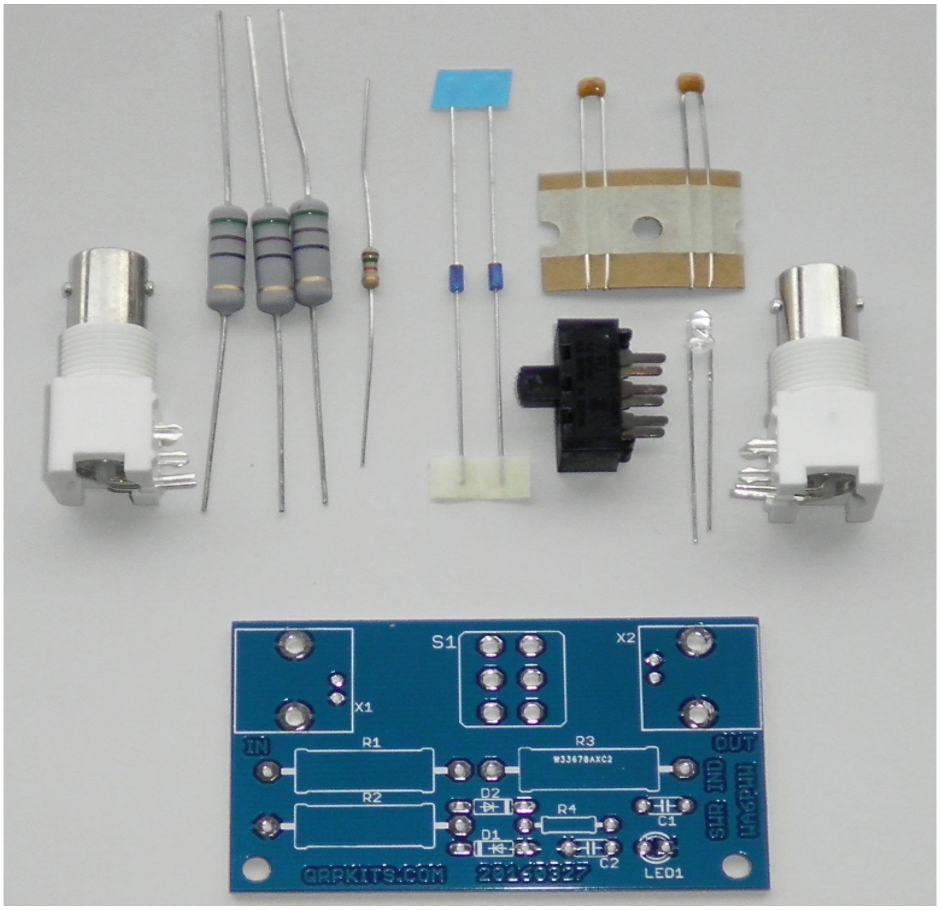
Here is one good example:
http://www.elecraft.com/TechNotes/N0SS_SolderNotes/N0SS_SolderNotesV6.pdf





Parts

Use the photograph to help identify parts in your kit. Note that in some cases parts may vary slightly in appearance from those shown.



Use the first column of the table below to check the parts as you inventory them and use the second column to check the parts as you install them.

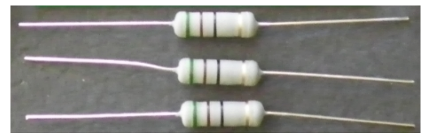
Parts Table

Inventory	Installed	Part #	Quantity	Description	Identification
		PCB	1	SWR IND	SWR IND
		R1,R2,R3	3	51 Ohm 2W resistor	GRN-BRN-BLK-GOLD
		R4	1	1.5K Ohm 1/4W resistor	BRN-GRN-RED-GOLD
		D1, D2	2	1N5711	Schottky Diode
		C1, C2	2	0.01uF Capacitor	Monolythic marked 103
		LED1	1	LED	LED
		S1	1	DPDT Switch	Metal frame or black plastic
		J1, J2	2	BNC	Board or Panel mount BNC

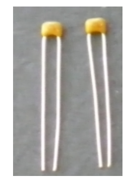
Inserting the Parts
Install the components listed in the table.
For resistors, and diodes, you can preform the leads by bending them down at a 90 degree angle.
Match the distance from the body to the holes in the circuit board where the part will be located.
Once each part is installed, bend its leads on the bottom of the board to hold it in place, solder the leads and clip off the excess lead.

Resistors
Locate and install the 1.5 k Ohm resistor R4 in the marked location on the board. It is the only small, ¼ watt resistor in the kit and is color coded Brown-Green-Red-Gold.

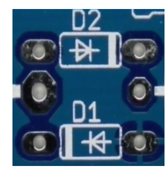
Now locate and install R1, R2 and R3 in the locations marked on the PC Board. These are larger body , 51 Ohm, 2W resistors with color code Green-Brown-Black-Gold.



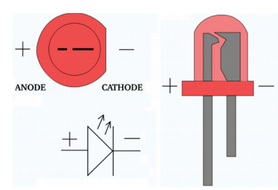
Capacitors
Install the capacitors C1 and C2 in the locations marked on the board. They do not have any specific orientation.



Diodes
Install the two Diodes D1 and D2, making sure to orient the diode bodies so that the band on the diode is on the same end as shown on the circuit board.



LED
Install the LED. It has specific polarity and must be installed only one way in the board or it will not work. It has one lead that is longer (the anode) and one shorter (the cathode)
The body of the LED will also usually have a flat on the same side as the short lead.
The circuit board has a round pad and square pad at the LED location. To install, insert the LED so that the short lead goes into the square pad on the board and the longer lead into the round pad.



BNCs

Note: If you plan to mount this kit in a case or build into another assembly where input and output connectors will not be needed or if you are using connectors to be mounted on the case you will not want to install the on board BNCs.

Solder the supplied BNC connectors on each end of the board in the positions marked J1 and J2. Be sure that the connectors are fully seated and then solder the support pins one at a time.

After the first support pin is soldered, recheck that the connector is seated on the board. If not, reheat the connector support pin while pressing down on the board to fully seat it.

Once the connectors are seated and both support pins are soldered, go ahead and solder the two signal connection pins (smaller) on each BNC.

Switch
Install the supplied DPDT switch in position S1 on the board. The orientation does not matter.

Solder 1 pin first and check that the switch is seated on the board. If not, heat the soldered pin while pressing the switch into the board and hold it while the solder solidifies.

Repeat this with a pin on the opposite end of the switch. This will hold it in place while the other 4 pins are soldered.

Checkout
Inspect the board for any bad solder joints, shorts or other problems and correct before use. Confirm for proper orientation of the LED and diodes.

Using a multi-meter in resistance mode, measure the resistance between the center and shell of the input BNC connector X1(or pads on the board if BNCs are not installed).

With the switch in bypass (toward the edge of the board, away from the diodes), the resistance should indicate open or infinite.

With the switch down toward the diodes to put the bridge in the circuit, you should see approximately 100 Ohms.

Repeat this check on the output BNC,
With the switch in bypass, you should also see infinite resistance and with the bridge switched in you should see approximately 150 Ohms.

Check resistance from the center of the input to the center of the output BNC.
With the bridge switched out (switch away from the diodes), you should see a very low resistance, less than 1 ohm.
With the switch down toward the diodes, you should measure approximately 50 Ohms

Congratulations, you have completed assembly or your Easy SWR Indicator Kit!

RF tests
We will perform functionality tests by connecting a transmitter (5W maximum) to the input of the Easy SWR Indicator.

Place the bridge in circuit by moving the switch to the position closest to the diodes.

Leave the output unconnected and very briefly key the transmitter.
You should see the LED light indicating correct installation of the diodes and LED.

To further test, if you have a 50Ohm load or dummy load, connect it to the output and briefly key the transmitter. The LED should not light.

This completes functional testing and you Easy SWR Indicator is ready to use!

Packaging
Packaging is left up to the builder. The kit can be used as is, built into another assembly or installed in a case.

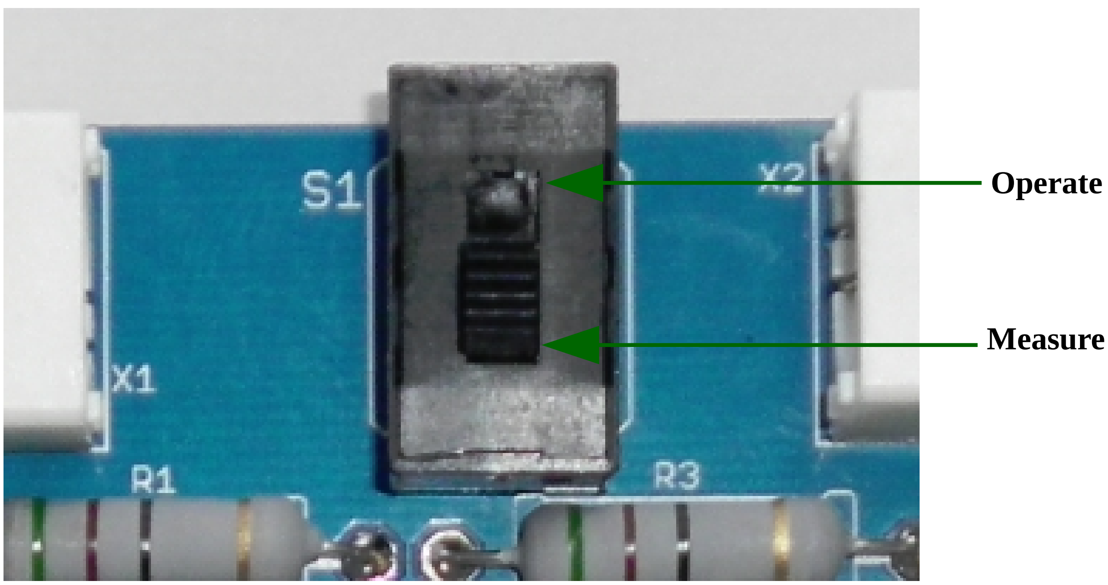
Usage
The Easy SWR Indicator provides a means to monitor the match between your antenna and transmitter to avoid damage and ensure maximum power transmission.

When the Switch S1 is toward the edge of the board, the bridge is bypassed.

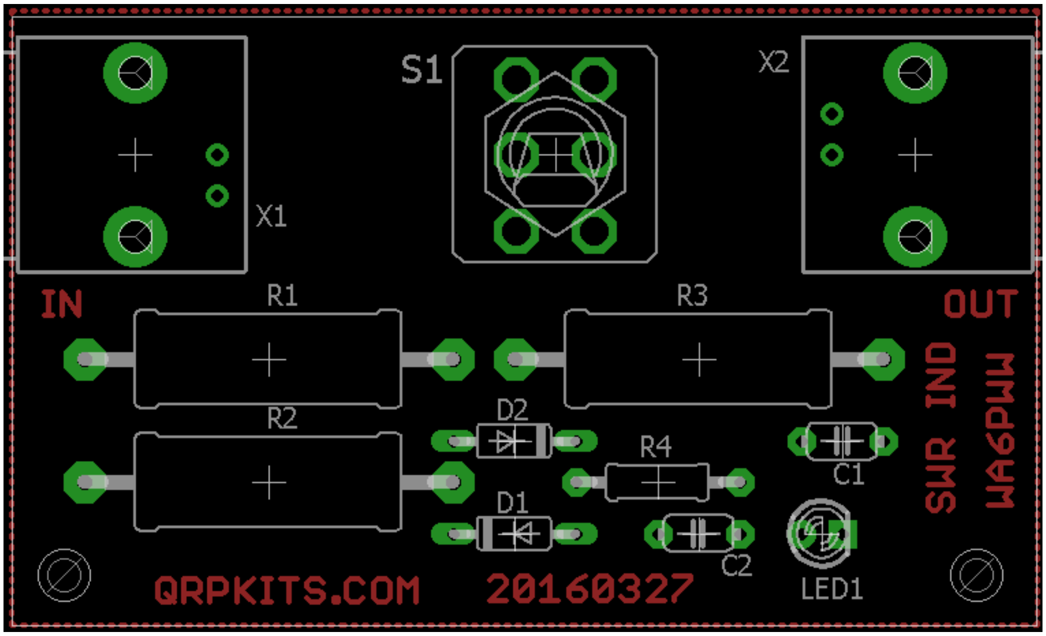
When the switch is down (toward the diodes), the bridge is in series with the antenna and will indicate mismatch by the brightness of the LED.

Adjusting your antenna or antenna tuner will cause the LED to dim and in most cases, completely extinguish when you have a good match.

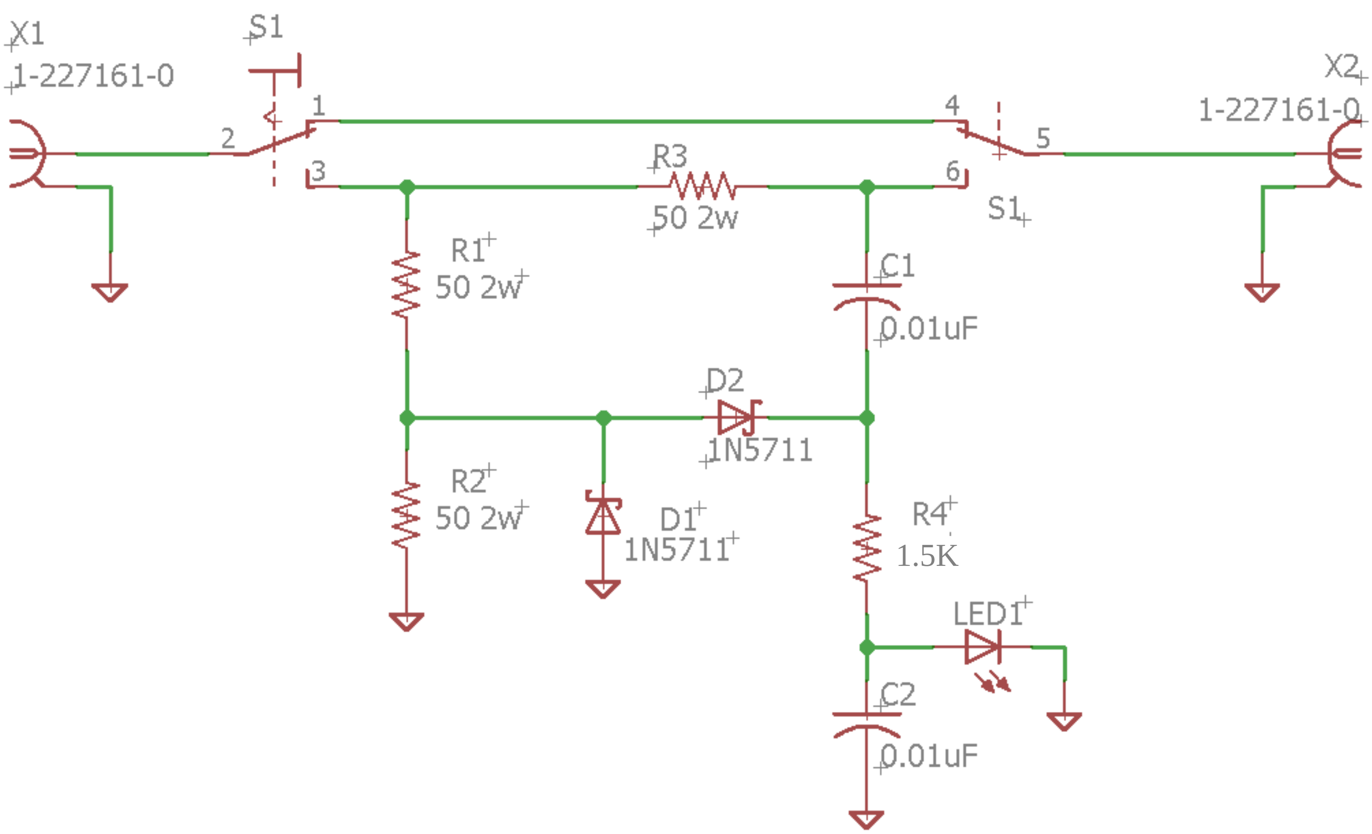
Once a match is achieved, switch the Easy SWR Indicator out of the circuit by placing the switch in bypass position as shown below.



Board Layout

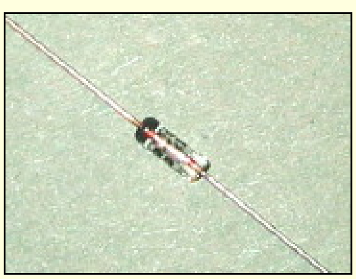


Schematic Diagram



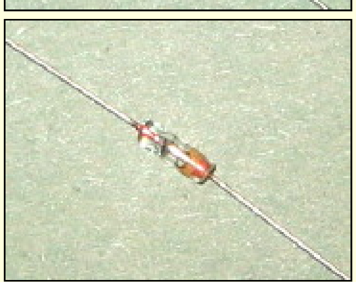
Home

DIODES



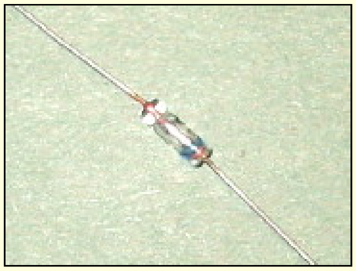
OA90 GERMANIUM DIODE

P/N
10-001
£ POA



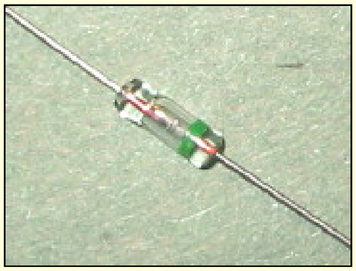
OA91 GERMANIUM DIODE

P/N
10-002
£ POA



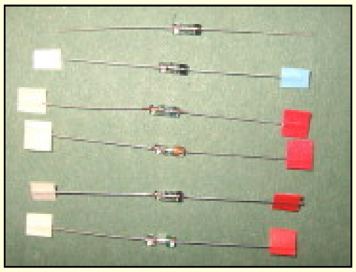
OA95 GERMANIUM DIODE

P/N
10-003
£ POA



1N34A GERMANIUM DIODE Larger view

P/N
10-005
£ POA



EXPERIMENTERS PACK Six Diodes OA90, OA91, OA95, 1N34A ,1N270, FD-1023-7B Larger view

P/N
10-011
£ POA

Lab 12 Electromagnetic Resonance: Building A Radio

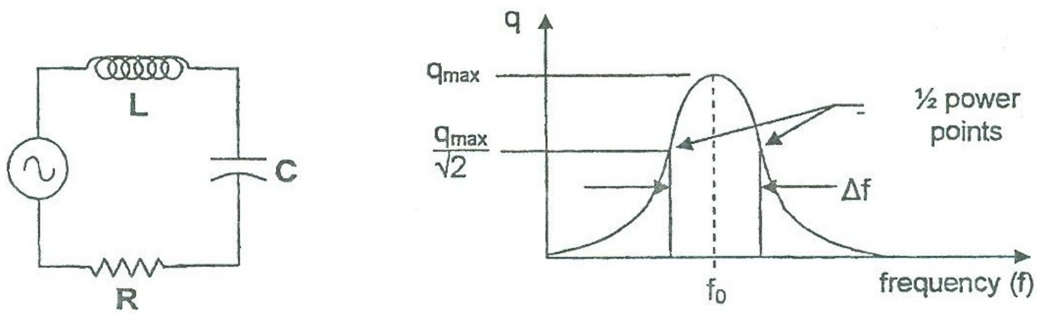
What You Need To Know:

The Physics Well, here you're going to apply what you learned in the LCR circuit lab. In fact we will go further and describe "forced" oscillation rather than just natural oscillation at resonance or ringing. In the previous lab 11, what you did was analogous to striking a bell and listening to the ringing.

Quick recap of LCR-circuit…

LCR circuit:

This is a perfect example of a damped driven harmonic oscillator which you will find throughout your studies in physics in mechanics as well as optics and electronics.



Series RLC circuit with graph of charge on the capacitor vs. frequency

Look at the voltage drops around the LCR circuit.

$\varepsilon = IR + L\frac{dI}{dt} + \frac{q}{C}$ divide this by L and using $I = \frac{dq}{dt}$ we get …

$\frac{d^2q}{dt^2} + \frac{R}{L}\frac{dq}{dt} + \frac{q}{LC} = \frac{\varepsilon}{L}$ where … $q(t) = q_o e^{-Rt/2L}\cos(\omega t + \phi)$

with the resonance frequency being … $\omega_o = 2\pi f_o = \frac{1}{\sqrt{LC}}$

From which we find the voltage across the capacitor as $V_C(t) = \frac{q(t)}{C}$ where $\tan\phi = \frac{X_L - X_C}{R}$ and $\omega = \sqrt{\left(\frac{R}{2L}\right)^2 - \omega_o^{\,2}}$ where $\omega_o = \frac{1}{\sqrt{LC}}$ is the natural or resonance frequency of the oscillator . We can write the supply max voltage $\varepsilon_o = I_o Z$.

The reactance's are defined as, $X_C = \frac{1}{\omega C}$ and $X_L = \omega L$.

The impedance Z is a complex quantity, $Z = R + i(X_L - X_C)$ you can find the magnitude and phase in the usual way.

$$|Z| = \sqrt{R^2 + (X_L - X_C)^2} \text{ and } Z = |Z|e^{i\phi} \text{ where } \phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

Also $\omega = 2\pi f$ where f is the frequency in Hz or per second. The frequency $f = \frac{1}{T}$ where T is the period of the oscillation. The impedance is a minimum when $X_L = X_C$. Then the natural frequency is given by $\omega = \omega_o = \frac{1}{\sqrt{LC}}$. When the two reactance's cancel out the circuit is purely resistive, that's when you get the natural frequency or resonance condition.

So now the new stuff…

Forced Oscillation:

If we try to drive the circuit at a frequency other than the natural frequency, with an ac supply say, then the circuit will respond only reluctantly so long as the driving freq is "close to" the natural freq.

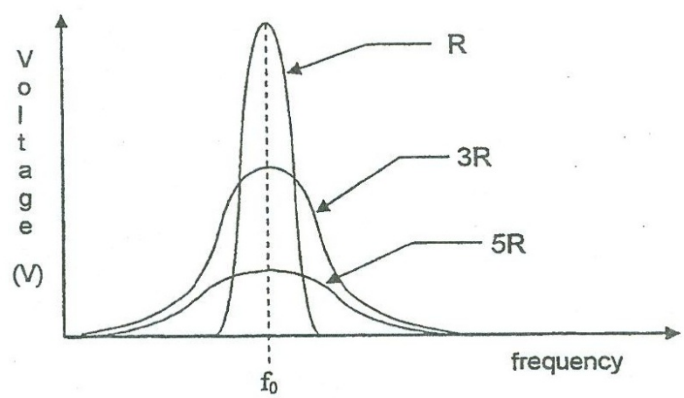
You may well ask how "close" will work. The frequency at which the amplitude of the charge on the capacitor reaches its maximum value is called the resonance freq (or natural freq). If you drive the circuit off resonance then the capacitor will never reach full charge. We need to choose driving frequencies that allow at least ½ of the maximum energy to be stored in the capacitor. In some circuits these two freq. may be far removed from the resonance freq. This would imply that there is a broad band of freq.'s that would excite the circuit. In other circuits you must have a freq very close to the resonance freq to get any excitation at all. This range of frequency is related to the quality factor of the circuit. See first diagram above. The sharpness of the resonance curve, is measured by the quality Factor Q. This is defined by $Q = f_0/\Delta f$ where f_0 is the resonance frequency and Δf is the band width or width of the resonance curve between the "half power" points.

Since the energy stored in a capacitor is given by $U = q^2/(2C)$, the half power points occur at $q_0/2^{1/2}$. (Maximum q is q_0). The quality factor is a dimensionless quantity. Large Q's correspond to sharply peaked curves while small Q's correspond to broad curves. Note that if f_0 is very large, then the Δf can be quite large and still be related to a sharply peaked resonance curve.

The band width, Δf, can be shown to be related to the decay constant $\tau = \dfrac{2L}{R}$ by

$$\Delta f = 1/(\pi\tau) = R/(2\pi L).$$

These expressions tell you that circuits which lose energy slowly (have large τ) will be very sharply peaked and can only be excited at freq's close to resonance. By contrast, those circuits that lose energy rapidly, have small τ, have very broad peaks and can be excited by a wide range of frequencies. For example, a bell made of brass, has a very definite pitch, a very narrow band width and will ring for a long time so has large τ. A wooden "chime" will not have a definite pitch, can be excited by a wide range of frequencies and has a sound that will die out quickly, small τ. Below are a few examples of resonance curves, all of which have the same resonance frequency $\omega_0 = 2\pi f_0 = (LC)^{-1/2}$, but different quality factors, Q. Note that L and C determine the resonant freq. but R and L determine the band width, $\Delta f = 1/(\pi\tau) = R/(2\pi L)$.



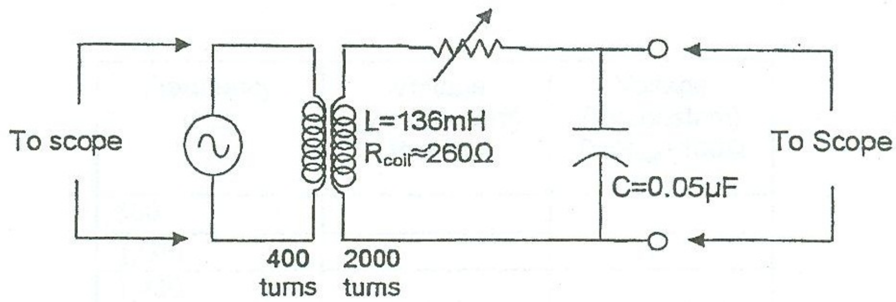
Graph of voltage vs. frequency for a series RLC circuit. Three curves are shown. The circuit for each curve has the same values of C and L but a different R as indicated.

What You Need To Do:

Experiment 1

In this experiment you will investigate the properties of an LCR circuit when subjected to a continuous sinusoidal applied voltage. In lab 11, you "whacked" the LCR circuit with bursts of energy via mutual inductance, using a primary coil hooked up to a square wave pulse generator. We watched the energy slosh back and forth between the capacitor and the inductor at a rate known as the resonance or natural frequency. Now we are going to drive the circuit continuously at a frequency which is NOT the natural oscillation freq of the circuit.

Hook up the circuit as shown on the next page.



Schematic of RLC circuit being driven by a sinusoidal voltage

We are trying to minimize the resistance because that will damp out the oscillation.

A) Set the signal generator to sinusoidal output.

B) Using the dual trace mode of the oscilloscope, you make the necessary connection so that you can simultaneously measure the voltage supplied by the signal generator to the energy injector coil (primary coil of 400 turns) and the voltage across the capacitor.

You are to determine the response of the circuit to signals of varying frequency. It would be best to hold the voltage from the signal generator constant... or as nearly constant as possible. The idea is that we want to isolate parameters and not change freq and voltage at the same time.

(Do a quick check to see how the voltage changes with different frequencies from the signal generator.)

Complete the table on the next page and graph your results of Voltage vs freq.

The first curve is for just the inductor resistance and a second curve on the same graph paper for the inductor resistance plus added resistance of 100 Ω. You should get two curves the first sharper than the second. It should look like the diagram on page 3.

You will be asked for the resonant frequency, the band width and the Q-factor, please fill those in on the sheet provided.

Name:______________________________

Phys 226 Lab 12

Frequency (Hz)	**Voltage (V)** **$R = R_{Coil}$**	**Voltage (V)** **$R = R_{Coil} + 100\ \Omega$**
500		
1,000		
1,400		
1,800		
2,000		
2,200		
2,400		
2,800		
3,200		
3,600		
4,000		
4,500		
5,000		
6,000		
7,000		
8,000		
10,000		

1) The resonance frequency, voltage output maximum across LC, f_0 =____________

The band width, Δf , is the width of the curve between power at ½ max points.

2) Find the band width Δf = ______________

3) The Q-factor = f_0 / Δf = ______________

4) Compare the two curves you plotted, the second at the higher resistance. What can you say about the band width and the Q-factor for the second curve?

Experiment 2: Building a simple Radio

Now you get to build a simple radio receiver. Once you have the receiver working you will be able to tune into an AM broadcast we are transmitting. Our broadcast contains super secret messages… if we told you what they were we'd have to kill you.

In the previous experiment you probably noticed that when the freq of the source (signal generator) was close to the resonant freq the amplitude of the voltage measured across the LC was increased. The frequency of the source can be made to match the resonant freq of the circuit. The reverse is also true. We can tune a circuit so that it matches the freq of the source… that's what you're doing every time you tune your car radio to your favorite station!

It is possible to tune (change) the natural frequency of an LCR circuit by adjusting the values of the component inductor and capacitor. Once the natural frequency of the circuit is brought close to the frequency of the radio source, the circuit will begin to oscillate in sympathy with the source and the voltage within the circuit will become large. We just need to build a circuit whose natural frequency can be adjusted within the radio freq band.

The radio band has a large range. We will be aiming at the medium frequency range, AM signals. AM is in the middle of the MF range, FM is in the upper half of the VHF range. Signals below 20 kHz are audio frequency or AF. (The audio band is 20 Hz to 20 KHz)

RF Spectrum Ranges:

Name	**Abbrv.**	**Range**
Very low freq	VLF	3 kHz - 30 kHz
Low freq	LF	30 kHz- 300 kHz
Medium freq	MF	300 kHz - 3 MHz
High freq	HF	3 MHz - 30 MHz
Very high freq	VHF	30 MHz- 300 MHz
Ultra high freq	UHF	300 MHz - 3 GHz
Super high freq	SHF	3 GHz - 30 GHz
Extremely high freq	EHF	30 GHz - 300 GHz

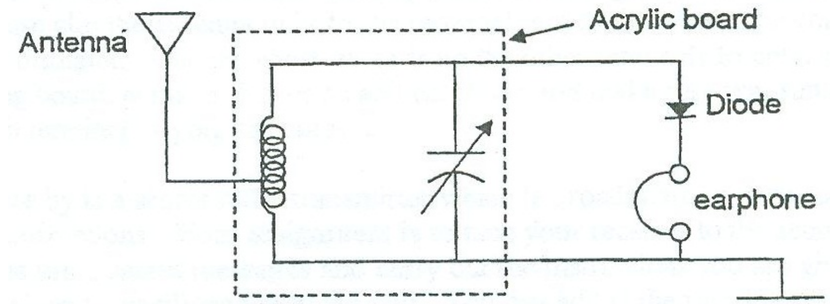
So let's say you have your circuit how do we get the electromagnetic energy "in the air" from the radio station into the circuit? Well, we need an antenna. Instead of connecting the primary coil to a signal generator we connect one end to a ground and the other to a wire antenna hooked up to the ceiling. We need the ground as a charge source.

You can dump a lot of charge into the ground and pull a lot of charge from the ground and the ground voltage always remains the same, zero. Very useful thing the ground!

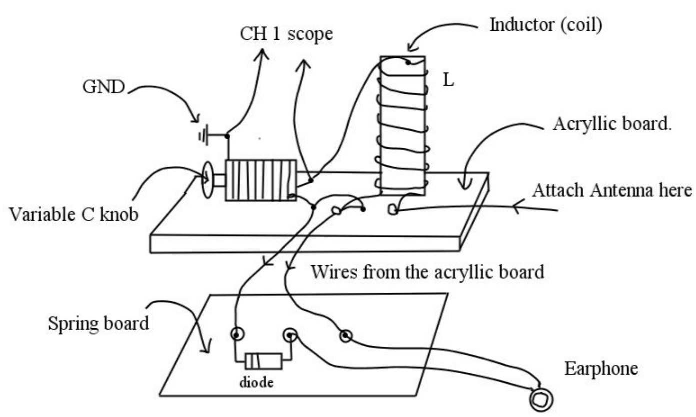
Radio waves are just time varying electromagnetic fields. When they hit the antenna, they will cause the electrons in the wire to oscillate and this causes a time dependent current to flow I(t). The changing magnetic field created by this current produces an EMF within the secondary coil which is part of the resonant circuit. That's it! You have captured energy from the radio wave. Now to hear the signal… we have to get the energy out?

The diode:

In the simplest terms a diode behaves in a circuit in a manner like a resistor, with the exception that they conduct current easily only in one direction. The symbol used for a diode is →|– which is intended , via the arrow, to show which way the current will flow from left to right in this case. We need to add on an earphone and a diode to the circuit and then we'll be able to get sound out. See diagram below;

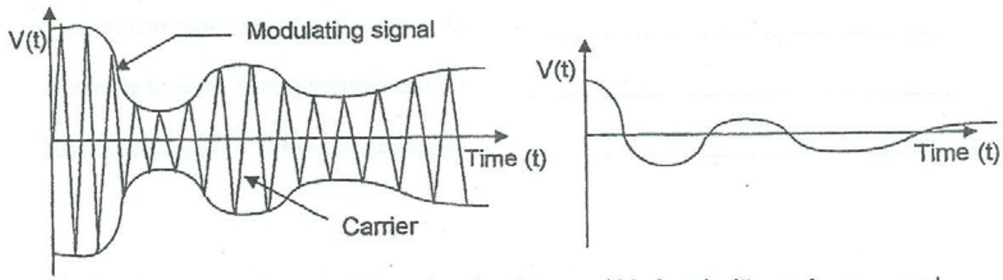


Schematic of basic radio receiver circuit



This is roughly how to set it all up. The knob is attached to a variable capacitor. This is how you will tune the circuit.

A typical amplitude modulated (AM) signal (current) which might be excited within your resonant circuit and the corresponding current that would flow through the earphone/ diode would look like the figure on the next page.

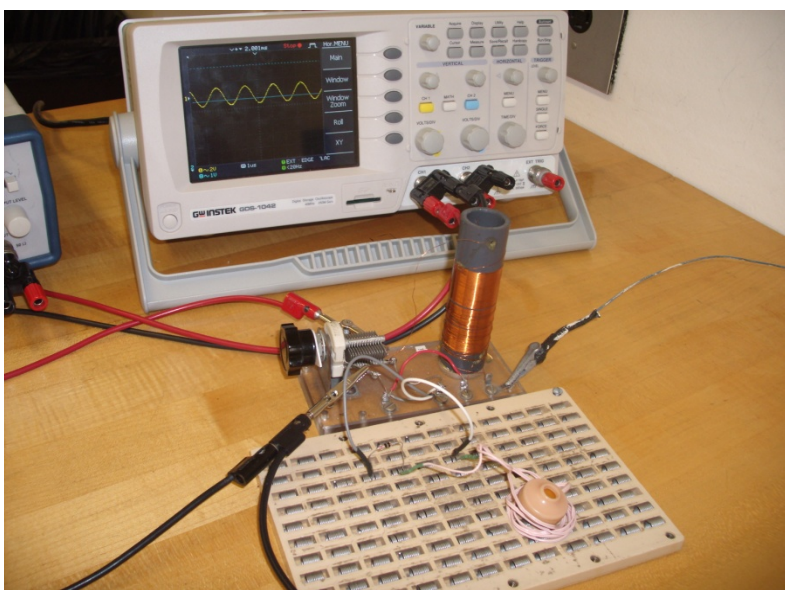


Amplitude modulated signal (AM) showing the carrier wave and modulating signal

AM signal with carrier removed

The reason why this wave form is called amplitude modulated (AM) is probably clear from the figure… the amplitude is constantly changing! The frequency of the wave, called the carrier frequency, is a constant and falls in the range from 535 kHz to 1605 kHz for the commercial AM broadcasts.

The carrier frequency is well above the highest audible sound 20 kHz. Note that while the frequency is constant the amplitude varies continuously at a frequency much lower than that of the carrier. The amplitude changes at a frequency in the audible range! That's what we want, the modulation frequency not the carrier frequency.



Enough talk… assemble the circuit as shown.

A) Your radio LCR circuit is supplied to you mounted on an acrylic base. The inductor is hand wound copper wire.

B) Connect the antennas coming from the ceiling to the rear terminal on the board. Please clip the antenna to the terminal not to the wire. The copper wire is fragile and not insulated.

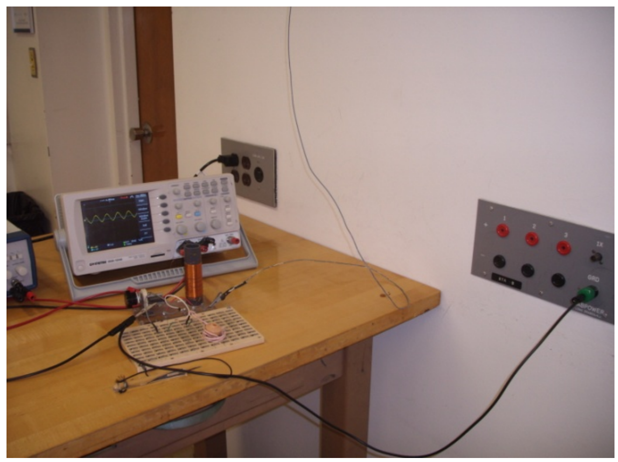
C) Use the short wires from the other terminals to connect your board to the spring board, connect the diode and earphone and make sure you run a ground wire to the green terminal at your lab station.

Hidden close by is a secret radio transmitter which is broadcasting a secret message. Your mission is to tap into the radio broadcast and take note of what it says.

You have been given an oscilloscope to assist you.

You can adjust the capacitance.. to tune the circuit, watch for a strong response on the scope, then listen in on the earphone.

Under no circumstances are you to divulge to anyone, beside your lab instructor, what you hear in these secret messages!!

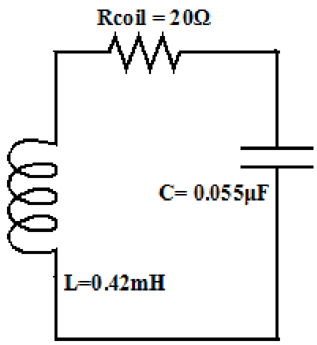


In the picture above you can see the antenna from the ceiling and the ground, green socket in the wall. You will have one at your station.

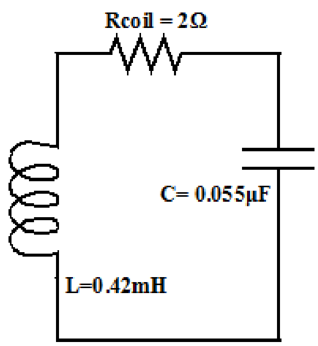
The Post Lab Activity is on the next page.

Post-Lab Activity

A) Plot the curve from the data on this page



Circuit #1



Circuit #2

Frequency (Hz)	**Voltage** Circuit #1 **(V)**	**Voltage** Circuit #2 **(V)**
10,000	0.038	0.038
15,000	0.065	0.065
20,000	0.106	0.109
24,000	0.165	0.174
26,000	0.212	0.234
28,000	0.280	0.338
29,000	0.325	0.427
30,000	0.377	0.572
31,000	0.432	0.848
32,000	0.478	1.560
32,400	0.491	2.280
32,800	0.498	3.760
33,130	0.500	5.000
33,400	0.499	4.080
33,800	0.492	2.480
34,200	0.482	1.690
35,000	0.451	1.020
36,000	0.405	0.682
37,000	0.359	0.514
38,000	0.320	0.415
40,000	0.258	0.301
45,000	0.172	0.184
50,000	0.130	0.135
55,000	0.106	0.108

For each of the 2 circuits shown, using the values of C and L given, predict the following from the equations:

1) The resonant freq's, f_0 .

2) The time constants for decay, τ.

3) The band widths for each circuit, Δf.

4) The quality or Q-factor for each circuit.

Now plot the curves of Volts vs Freq and get all the same 4 results from the graph.

An answer sheet is provided for your results.

This may be kept as a post lab exercise, up to the instructor.

Name:______________________________

Physics 226L
Experiment#12
Electromagnetic Resonance: Building a Radio

Post-Lab Answer Sheet

Theory Results:

Circuit	**f_o ($f_{resonance}$) (Hz)**	**τ (s)**	**Δf (Hz)**	**Q**
#1 (R=20Ω)				
#2 (R=2Ω)				

Graph Results:

Circuit	**f_o ($f_{resonance}$) (Hz)**	**τ (s)**	**Δf (Hz)**	**Q**
#1 (R=20Ω)				
#2 (R=2Ω)				

Lab 12 Electromagnetic Resonance: Building A Radio

What You Need To Know:

The Physics Well, here you're going to apply what you learned in the LCR circuit lab. In fact we will go further and describe "forced" oscillation rather than just natural oscillation at resonance or ringing. In the previous lab 11, what you did was analogous to striking a bell and listening to the ringing.

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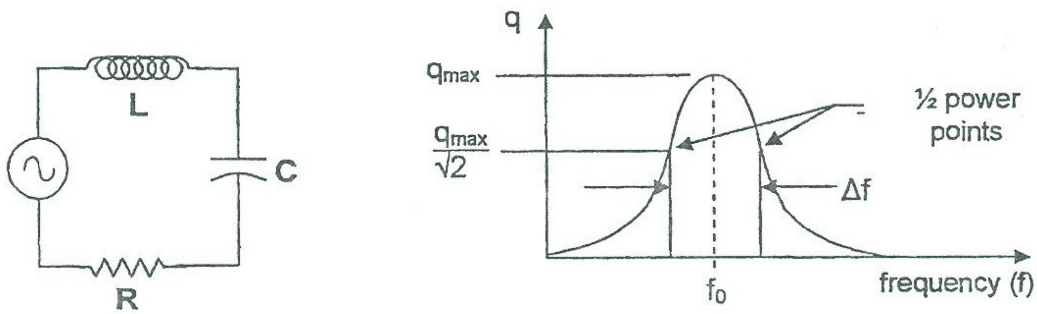
This is a perfect example of a damped driven harmonic oscillator which you will find throughout your studies in physics in mechanics as well as optics and electronics.



Series RLC circuit with graph of charge on the capacitor vs. frequency

Look at the voltage drops around the LCR circuit.

$\varepsilon = IR + L\dfrac{dI}{dt} + \dfrac{q}{C}$ divide this by L and using $I = \dfrac{dq}{dt}$ we get …

$\dfrac{d^2q}{dt^2} + \dfrac{R}{L}\dfrac{dq}{dt} + \dfrac{q}{LC} = \dfrac{\varepsilon}{L}$ where … $q(t) = q_o e^{-Rt/2L}\cos(\omega t + \phi)$

with the resonance frequency being … $\omega_o = 2\pi f_o = \dfrac{1}{\sqrt{LC}}$

From which we find the voltage across the capacitor as $V_C(t) = \dfrac{q(t)}{C}$ where $\tan\phi = \dfrac{X_L - X_C}{R}$ and $\omega = \sqrt{\left(\dfrac{R}{2L}\right)^2 - \omega_o^2}$ where $\omega_o = \dfrac{1}{\sqrt{LC}}$ is the natural or resonance frequency of the oscillator. We can write the supply max voltage $\varepsilon_o = I_o Z$.

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The impedance Z is a complex quantity, $Z = R + i(X_L - X_C)$ you can find the magnitude and phase in the usual way.

$$|Z| = \sqrt{R^2 + (X_L - X_C)^2} \text{ and } Z = |Z|e^{i\phi} \text{ where } \phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

Also $\omega = 2\pi f$ where f is the frequency in Hz or per second. The frequency $f = \dfrac{1}{T}$ where T is the period of the oscillation. The impedance is a minimum when $X_L = X_C$. Then the natural frequency is given by $\omega = \omega_o = \dfrac{1}{\sqrt{LC}}$. When the two reactance's cancel out the circuit is purely resistive, that's when you get the natural frequency or resonance condition.

So now the new stuff…

Forced Oscillation:

If we try to drive the circuit at a frequency other than the natural frequency, with an ac supply say, then the circuit will respond only reluctantly so long as the driving freq is "close to" the natural freq.

You may well ask how "close" will work. The frequency at which the amplitude of the charge on the capacitor reaches its maximum value is called the resonance freq (or natural freq). If you drive the circuit off resonance then the capacitor will never reach full charge. We need to choose driving frequencies that allow at least ½ of the maximum energy to be stored in the capacitor. In some circuits these two freq. may be far removed from the resonance freq. This would imply that there is a broad band of freq.'s that would excite the circuit. In other circuits you must have a freq very close to the resonance freq to get any excitation at all. This range of frequency is related to the quality factor of the circuit. See first diagram above. The sharpness of the resonance curve, is measured by the quality Factor Q. This is defined by $Q = f_0/\Delta f$ where f_0 is the resonance frequency and Δf is the band width or width of the resonance curve between the "half power" points.

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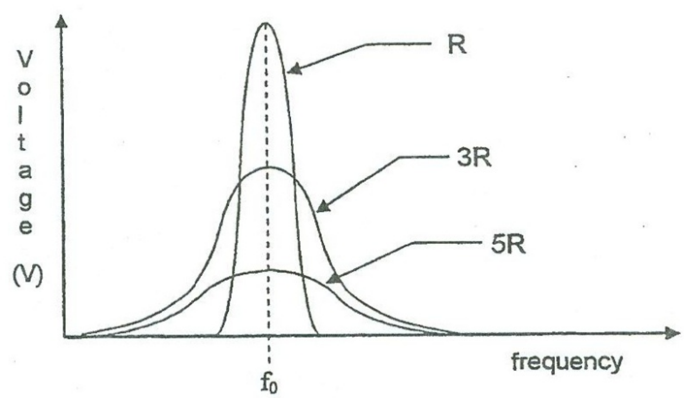
These expressions tell you that circuits which lose energy slowly (have large τ) will be very sharply peaked and can only be excited at freq's close to resonance. By contrast, those circuits that lose energy rapidly, have small τ, have very broad peaks and can be excited by a wide range of frequencies. For example, a bell made of brass, has a very definite pitch, a very narrow band width and will ring for a long time so has large τ. A wooden "chime" will not have a definite pitch, can be excited by a wide range of frequencies and has a sound that will die out quickly, small τ. Below are a few examples of resonance curves, all of which have the same resonance frequency $\omega_0 = 2\pi f_0 = (LC)^{-1/2}$, but different quality factors, Q. Note that L and C determine the resonant freq. but R and L determine the band width, $\Delta f = 1/(\pi\tau) = R/(2\pi L)$.



Graph of voltage vs. frequency for a series RLC circuit. Three curves are shown. The circuit for each curve has the same values of C and L but a different R as indicated.

What You Need To Do:

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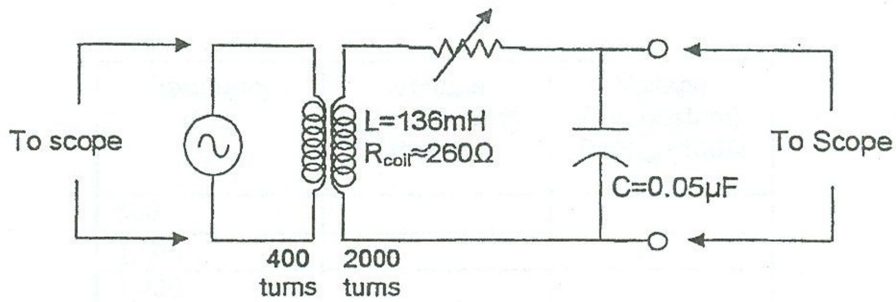
In this experiment you will investigate the properties of an LCR circuit when subjected to a continuous sinusoidal applied voltage. In lab 11, you "whacked" the LCR circuit with bursts of energy via mutual inductance, using a primary coil hooked up to a square wave pulse generator. We watched the energy slosh back and forth between the capacitor and the inductor at a rate known as the resonance or natural frequency. Now we are going to drive the circuit continuously at a frequency which is NOT the natural oscillation freq of the circuit.

Hook up the circuit as shown on the next page.



Schematic of RLC circuit being driven by a sinusoidal voltage

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B) Using the dual trace mode of the oscilloscope, you make the necessary connection so that you can simultaneously measure the voltage supplied by the signal generator to the energy injector coil (primary coil of 400 turns) and the voltage across the capacitor.

You are to determine the response of the circuit to signals of varying frequency. It would be best to hold the voltage from the signal generator constant... or as nearly constant as possible. The idea is that we want to isolate parameters and not change freq and voltage at the same time.

(Do a quick check to see how the voltage changes with different frequencies from the signal generator.)

Complete the table on the next page and graph your results of Voltage vs freq.

The first curve is for just the inductor resistance and a second curve on the same graph paper for the inductor resistance plus added resistance of 100 Ω. You should get two curves the first sharper than the second. It should look like the diagram on page 3.

You will be asked for the resonant frequency, the band width and the Q-factor, please fill those in on the sheet provided.

Name:______________________________

Phys 226 Lab 12

Frequency (Hz)	**Voltage (V)** **R = R_{Coil}**	**Voltage (V)** **R = R_{Coil} + 100 Ω**
500		
1,000		
1,400		
1,800		
2,000		
2,200		
2,400		
2,800		
3,200		
3,600		
4,000		
4,500		
5,000		
6,000		
7,000		
8,000		
10,000		

1) The resonance frequency, voltage output maximum across LC, f_0 =____________

The band width, Δf , is the width of the curve between power at ½ max points.

2) Find the band width Δf = ______________

3) The Q-factor = f_0 / Δf = ______________

4) Compare the two curves you plotted, the second at the higher resistance. What can you say about the band width and the Q-factor for the second curve?

Experiment 2: Building a simple Radio

Now you get to build a simple radio receiver. Once you have the receiver working you will be able to tune into an AM broadcast we are transmitting. Our broadcast contains super secret messages… if we told you what they were we'd have to kill you.

In the previous experiment you probably noticed that when the freq of the source (signal generator) was close to the resonant freq the amplitude of the voltage measured across the LC was increased. The frequency of the source can be made to match the resonant freq of the circuit. The reverse is also true. We can tune a circuit so that it matches the freq of the source… that's what you're doing every time you tune your car radio to your favorite station!

It is possible to tune (change) the natural frequency of an LCR circuit by adjusting the values of the component inductor and capacitor. Once the natural frequency of the circuit is brought close to the frequency of the radio source, the circuit will begin to oscillate in sympathy with the source and the voltage within the circuit will become large. We just need to build a circuit whose natural frequency can be adjusted within the radio freq band.

The radio band has a large range. We will be aiming at the medium frequency range, AM signals. AM is in the middle of the MF range, FM is in the upper half of the VHF range. Signals below 20 kHz are audio frequency or AF. (The audio band is 20 Hz to 20 KHz)

RF Spectrum Ranges:

Name	**Abbrv.**	**Range**
Very low freq	VLF	3 kHz - 30 kHz
Low freq	LF	30 kHz- 300 kHz
Medium freq	MF	300 kHz - 3 MHz
High freq	HF	3 MHz - 30 MHz
Very high freq	VHF	30 MHz- 300 MHz
Ultra high freq	UHF	300 MHz - 3 GHz
Super high freq	SHF	3 GHz - 30 GHz
Extremely high freq	EHF	30 GHz - 300 GHz

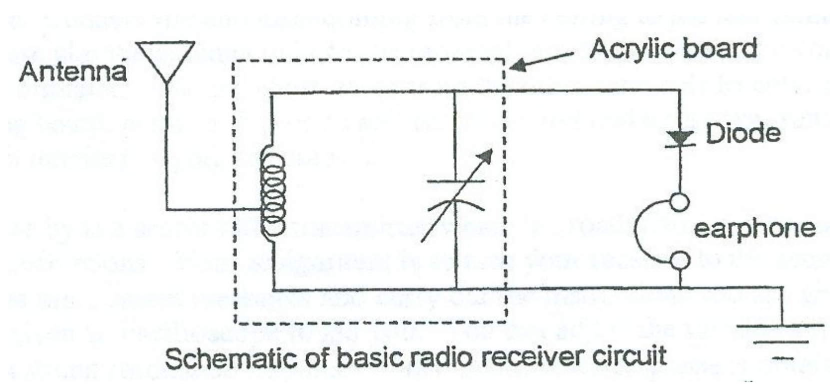
So let's say you have your circuit how do we get the electromagnetic energy "in the air" from the radio station into the circuit? Well, we need an antenna. Instead of connecting the primary coil to a signal generator we connect one end to a ground and the other to a wire antenna hooked up to the ceiling. We need the ground as a charge source.

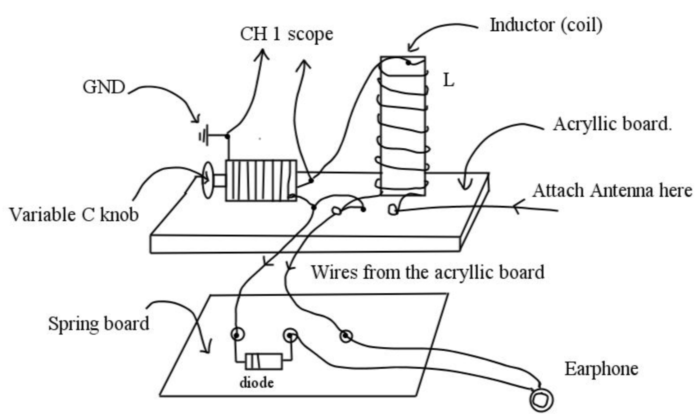
You can dump a lot of charge into the ground and pull a lot of charge from the ground and the ground voltage always remains the same, zero. Very useful thing the ground!

Radio waves are just time varying electromagnetic fields. When they hit the antenna, they will cause the electrons in the wire to oscillate and this causes a time dependent current to flow I(t). The changing magnetic field created by this current produces an EMF within the secondary coil which is part of the resonant circuit. That's it! You have captured energy from the radio wave. Now to hear the signal… we have to get the energy out?

The diode:

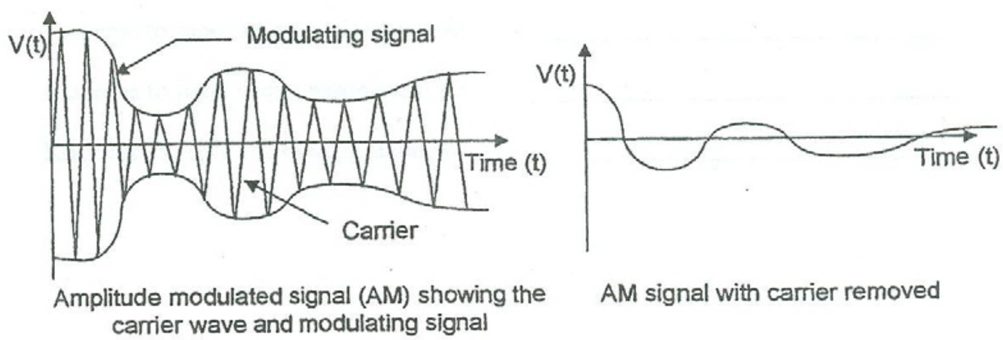
In the simplest terms a diode behaves in a circuit in a manner like a resistor, with the exception that they conduct current easily only in one direction. The symbol used for a diode is →|─ which is intended , via the arrow, to show which way the current will flow from left to right in this case. We need to add on an earphone and a diode to the circuit and then we'll be able to get sound out. See diagram below;





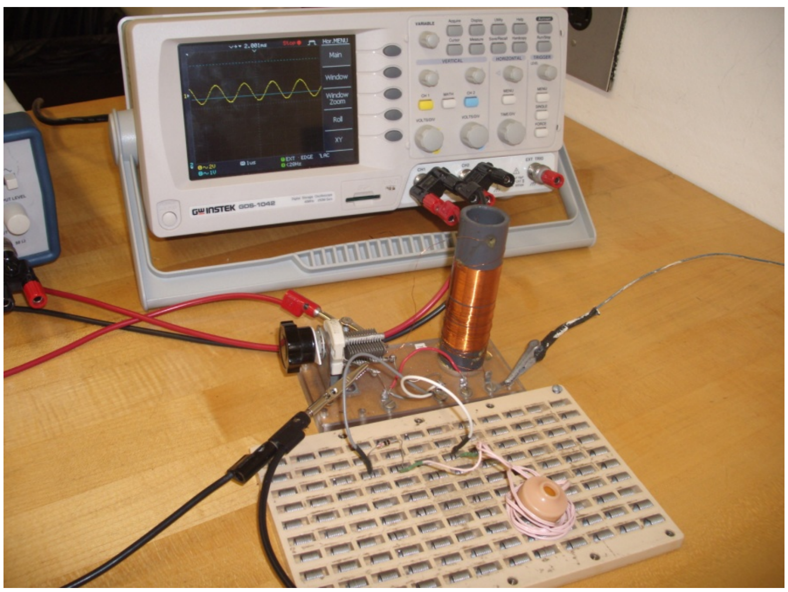
This is roughly how to set it all up. The knob is attached to a variable capacitor. This is how you will tune the circuit.

A typical amplitude modulated (AM) signal (current) which might be excited within your resonant circuit and the corresponding current that would flow through the earphone/ diode would look like the figure on the next page.



The reason why this wave form is called amplitude modulated (AM) is probably clear from the figure… the amplitude is constantly changing! The frequency of the wave, called the carrier frequency, is a constant and falls in the range from 535 kHz to 1605 kHz for the commercial AM broadcasts.

The carrier frequency is well above the highest audible sound 20 kHz. Note that while the frequency is constant the amplitude varies continuously at a frequency much lower than that of the carrier. The amplitude changes at a frequency in the audible range! That's what we want, the modulation frequency not the carrier frequency.



Enough talk… assemble the circuit as shown.

A) Your radio LCR circuit is supplied to you mounted on an acrylic base. The inductor is hand wound copper wire.

B) Connect the antennas coming from the ceiling to the rear terminal on the board. Please clip the antenna to the terminal not to the wire. The copper wire is fragile and not insulated.

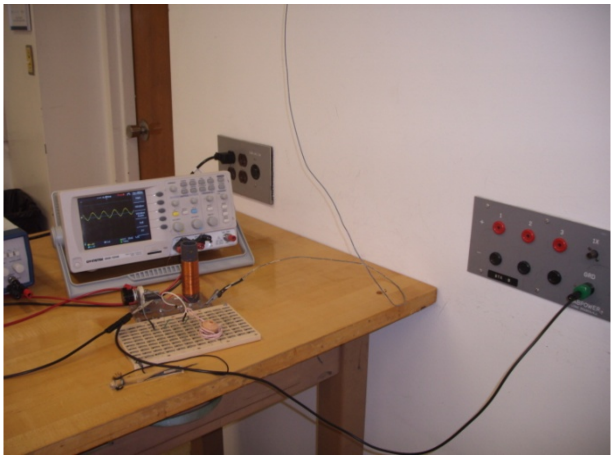
C) Use the short wires from the other terminals to connect your board to the spring board, connect the diode and earphone and make sure you run a ground wire to the green terminal at your lab station.

Hidden close by is a secret radio transmitter which is broadcasting a secret message. Your mission is to tap into the radio broadcast and take note of what it says.

You have been given an oscilloscope to assist you.

You can adjust the capacitance.. to tune the circuit, watch for a strong response on the scope, then listen in on the earphone.

Under no circumstances are you to divulge to anyone, beside your lab instructor, what you hear in these secret messages!!

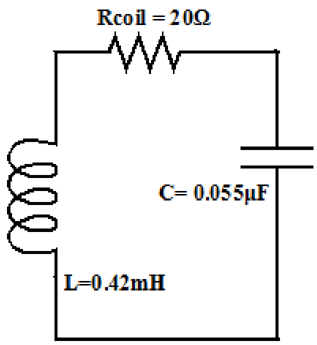


In the picture above you can see the antenna from the ceiling and the ground, green socket in the wall. You will have one at your station.

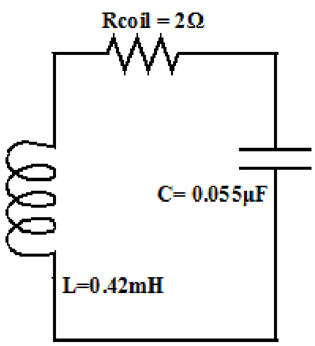
The Post Lab Activity is on the next page.

Post-Lab Activity

A) Plot the curve from the data on this page



Circuit #1



Circuit #2

Frequency (Hz)	**Voltage** Circuit #1 **(V)**	**Voltage** Circuit #2 **(V)**
10,000	0.038	0.038
15,000	0.065	0.065
20,000	0.106	0.109
24,000	0.165	0.174
26,000	0.212	0.234
28,000	0.280	0.338
29,000	0.325	0.427
30,000	0.377	0.572
31,000	0.432	0.848
32,000	0.478	1.560
32,400	0.491	2.280
32,800	0.498	3.760
33,130	0.500	5.000
33,400	0.499	4.080
33,800	0.492	2.480
34,200	0.482	1.690
35,000	0.451	1.020
36,000	0.405	0.682
37,000	0.359	0.514
38,000	0.320	0.415
40,000	0.258	0.301
45,000	0.172	0.184
50,000	0.130	0.135
55,000	0.106	0.108

For each of the 2 circuits shown, using the values of C and L given, predict the following from the equations:

1) The resonant freq's, f_0 .

2) The time constants for decay, τ.

3) The band widths for each circuit, Δf.

4) The quality or Q-factor for each circuit.

Now plot the curves of Volts vs Freq and get all the same 4 results from the graph.

An answer sheet is provided for your results.

This may be kept as a post lab exercise, up to the instructor.

Name:______________________________

Physics 226L
Experiment#12
Electromagnetic Resonance: Building a Radio

Post-Lab Answer Sheet

Theory Results:

Circuit	f_o ($f_{resonance}$) (Hz)	τ (s)	Δf (Hz)	Q
#1 (R=20Ω)				
#2 (R=2Ω)				

Graph Results:

Circuit	f_o ($f_{resonance}$) (Hz)	τ (s)	Δf (Hz)	Q
#1 (R=20Ω)				
#2 (R=2Ω)				

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Vehicular Radio Scanner Using Phased Array Antenna for Dedicated Short Range Communication Service

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ABSTRACT

Now a day's accidents are very common due to increased population of vehicle. In order to ensure safety measures in the vehicle this paper has proposed some methodologies regarding careful driving by automatically scanning and analyzing the blind spot area of an intelligent mobile vehicle. A vehicular antenna with minimum perturbation is proposed to be fitted on the vehicle and collect information of the concern area which would ensure visibility of the operator *i.e.* masked or integrated within the car body. This paper has dealt with the design of Tchebyscheff polynomial based prototype planar microstrip phased array antenna and also redesigned the same when implemented in the body of the car being considered as an electromagnetically large element. Both the design has been experimentally verified with the measurement. The simulated and the measured results in both the cases are found to be in good agreement. More than 11 dB gain was observed at perfectly 30° angles from its broad side direction as desired for blind spot detection with minimum amount of electromagnetic interference inside the car.

Keywords: Intelligent Transportation System; Microstrip Phased Array Antenna; Tchebyscheff Polynomial; Electromagnetic Interference

1. Introduction

Intelligent Transport System (ITS) ensures mobility comfort and safety in transportation system. It also absorbs the hazards due to environmental impact. With the progress of the information processing technology, control systems to minimize accidents for the roadways have also been advanced hence one approach to improve the traffic safety is found and that is automatic collection of data by scanning the blind spot area of the vehicle [1] as shown in **Figure 1**. Many methods were proposed to detect the blind spot area but all of them had certain limitations. Devices like dynamic angling side view mirror [2], side view camera model [3], and shadow or edge features detector [4] were used for detecting blind spot area but their performance was affected during bad weather, fog or mist. Also we know that the mechanical systems, response time is more and the system is prone to wear and tear.

A radio frequency method has been proposed in this paper to scan the blind spot zone efficiently. Four rectangular microstrip antennas (RMSA) are arranged in linear configuration with optimal spacing between the patch elements to construct the phased array radar. A corporate feed network is used to feed the patch element unequally and a progressive phase shifter is designed with 108˚ delay elements to tilt the main beam in the desired direction and then the total unit is simulated and experimented after placing it on the car body which is electromagnetically a large element. The antenna works in the Dedicated Short-Range Communication Service (DSRCS) frequency band [5]. The design of the microstrip phased array antenna is discussed in Section 2 and after that to place the antenna; the design of the entire car is given in Section 3. Results and discussion are portrayed in Section 4 along with conclusion in Section 5.

2. Design of Microstrip Phased Array Antenna

The microstrip phased array antenna is designed for Dedicated Short Range Communication Service at 5.88 GHz with dielectric constant of 2.32 and substrate thickness of 0.785 mm. Firstly the dimension of the rectangular patch is computed as 16.322 mm by 19.8 mm using the method outlined in [6]. With computed inset feed length of 3.8 mm and for the above dimensions of the rectangular patch the return loss is found to be –8.09 dB

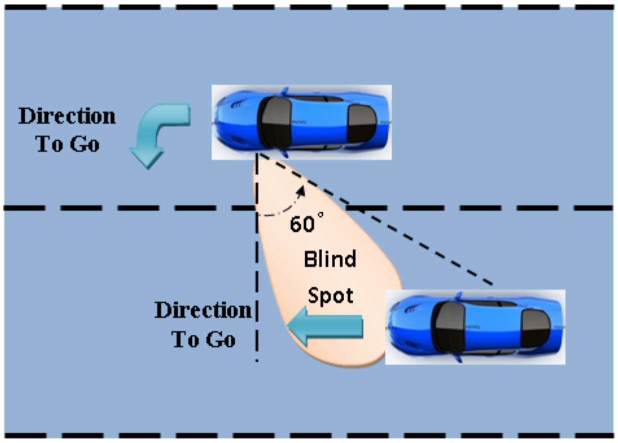


Figure 1. Surrounding regions of a vehicle.

with (30.1 + j26.7) ohm impedance at the feed position. The RMSA is simulated and optimized using Ansoft HFSS™. After optimization the final length is found to be 16.4363 mm with inset feed length of 4.8225 mm keeping the width of the patch unchanged as shown in **Figure 2**.

By considering the above designed patch element, a four element linear array is realized and powered by Tchebyscheff current distribution. The spacing between the elements is kept considering the desired maximum scan angle in order to eliminate the grating lobes within the visible space of the phased array antenna. To optimize the performance of the antenna in respect of its side lobe level (SLL), mutual coupling and gain of the antenna array, the spacing between the elements is studied parametrically [7]. The results of the said study are tabulated in **Table 1**.

After optimization it is found that the optimum spacing between the elements is 0.6 λ_0 while considering, the main lobe to side lobe ratio below 20 dB, optimum mutual coupling and overall gain.

From **Figure 1**, it is observed that the beam of the antenna array is required to be tilted by an angle 30˚ away from the broad side direction. In view of the above a progressive phase shifter of –108˚ is designed with the help of 11.16 mm feed line length. The actual line length is considered as mτ, where m = 0, 1, 2, 3.

To enhance the gain by maintaining the beam width and main lobe to side lobe ratio, the antenna elements are excited by Dolph Chebyshev current distribution. The array consist of four elements, thus third order Tchebyscheff polynomial is calculated. Hence the polynomial is solved and relative current ratio is computed as 1:1.7795:1.7795:1. Both equal and unequal power dividers are designed along with the progressive phase shifter.

For equal power division, a 3 dB equal power divider is designed whose vertical arm is of 50 Ω line and two horizontal quarter-wavelength branch-lines are of 70.71 Ω is used [8]. It is shown in **Figure 3(a)**.

Table 1. Effect on mutual coupling and gain due to variation in spacing (d) between the elements.

d with respect to guided wavelength	d with respect to operating wavelength	Mutual coupling (dB)	Gain (dBi)
0.6 λ_g	0.41 λ_0	>10	7.6
0.7 λ_g	0.48 λ_0	>13	9.9412
0.8 λ_g	0.55 λ_0	>20	10.647
0.9 λ_g	0.6 λ_0	>22	10.919

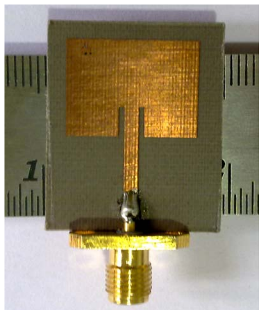


Figure 2. Photograph of the rectangular microstrip antenna element.

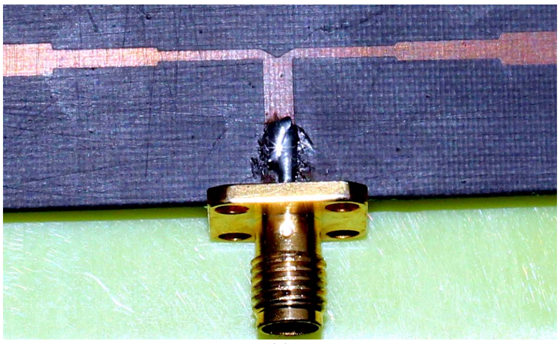
To get the unequal current distribution, both the horizontal arm of the microstrip unequal power divider should be of different resistance and it is calculated as 46.368 Ω and 82.49 Ω. The structure is shown in **Figure 3(b)**.

Generally for practical design purpose the gap between the corporate feed networks is taken small but the value of the gap less than 0.11 λ_0 disturbs the frequency response of overall antenna array. The effects of the feed network on the side-lobes are significant in the E-plane pattern. The influence on the H-plane is less important due to the orthogonality of the drive current and the symmetry of all the other currents in this cut [9]. By maintaining the SLL and the surface wave loss, the gaps are taken as 0.11 λ_0 as portrayed in **Figure 4**.

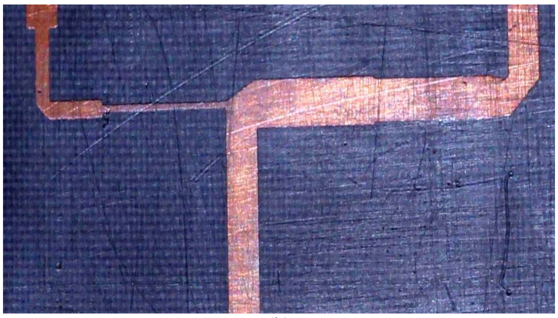
3. Placement of Antenna on the Vehicle

In order to compute the electromagnetic effect of the body of the car on the antenna performance, the entire structure of the car is designed in Ansoft HFSS™. The complete structure of the car consist of hood, roof, trunk, left and right side doors, left and right side quarter panel for front and rear side which are made up of conducting material but the bumpers and wheels are assigned by layered impedance due to their hard rubber and polyester materials as shown in **Figure 5**.

After going through the typical requirement for scanning the blind spot, the antenna is placed just beside the side view mirror. The following problems in the designed are addressed while simulating the effect of the radiation



(a)



(b)

Figure 3. (a) Photograph of the equal microstrip power divider; (b) Photograph of the unequal microstrip power divider.

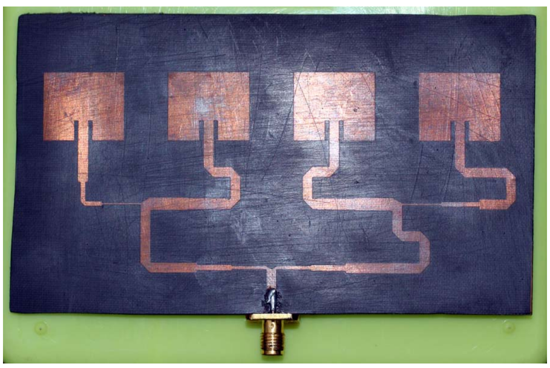


Figure 4. Photograph of the antenna array with corporate feed network.

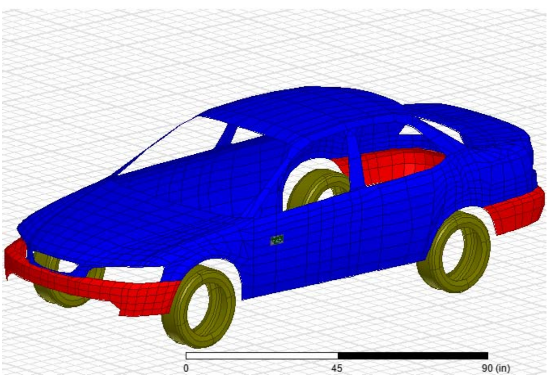


Figure 5. The entire structure of the car along with the antenna array.

characteristics of the antenna after placing it on the vehicle:

1) Spans a large computational domain compared to the wavelength;

2) Requires a fine grid resolution to resolve the detailed antenna structure;

3) Contains largely non-conformal PEC and dielectric structures.

4. Results and Discussion

For obtaining the scattering parameter characteristics, the microstrip antenna has been simulated over the frequency bandwidth ranging from 5.5 GHz to 6.5 GHz and two different circumstances is observed. The first experiments involve the design, simulation and measurement after fabrication of an individual element and then the array with the same without involving the effect of the car. Both of them should used for optimized performance.

The scattering parameter is measured by Agilent Technology Vector Network Analyzer model no. N5320A (10 MHz - 20 GHz) and the radiation pattern is measured by Hittite HMC-T2100 synthesized signal generator (10 MHz - 20 GHz) and Krytar 9000 B power meter (10 MHz - 40 GHz) with 9530 B power sensor (10 MHz - 20 GHz) as shown in **Figure 6**. From **Figure 7**, it is found

(a)

(b)

Figure 6. (a) Experimental set-up to measure the radiation pattern of the antenna array; (b) Experimental set-up to measure the radiation pattern of the antenna array after placing it on the car.

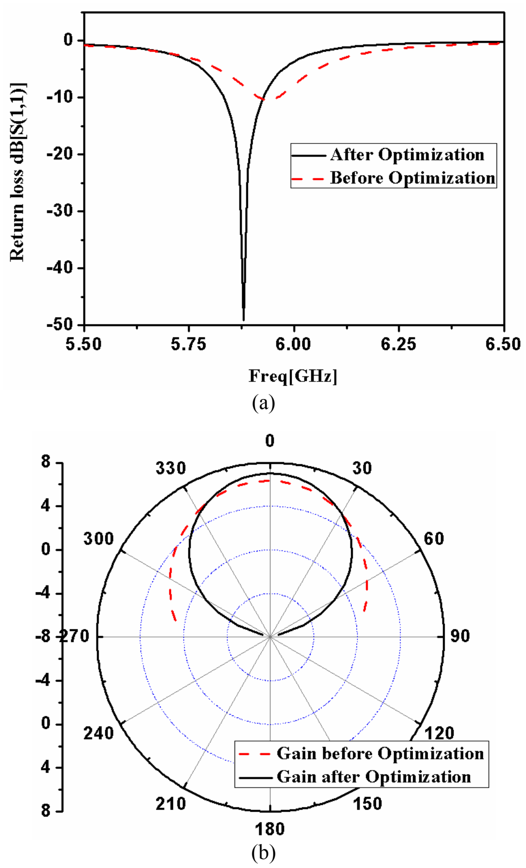


Figure 7. (a) Return loss a single patch before and after optimization; (b) Gain of a single patch before and after optimization.

that after optimization a perfect match is obtained exactly at 5.88 GHz and gain is also improved from 6.33 dB to 7.01 dB with a very good return loss of –47 dB. The current distribution and the radiation pattern of a single RMSA is portrayed in **Figure 8**.

A parametric study of the return loss of antenna array with different spacing between the elements of the corporate feed network is done and is compared in **Figure 9**. The results of the computational model of the entire antenna array with feed network were compared with the measured data and a good agreement is observed in **Figure 10**.

After getting the satisfactory results, next the same array antenna is experimented again with considering the electromagnetic effect of the car. In order to test the antenna array in association with the vehicle, a numerical model of the car is created using Ansoft HFSS^{TM} and the simulated data is compared with the measured in **Figure 11**. **Figure 12** graphically represents the 3D radiation pattern of the antenna array in presence of the computational model of the vehicle. From **Figure 13**, it is clear that the inside electric field strength is not more than 15 Volt per meter which is very less compare to the standard

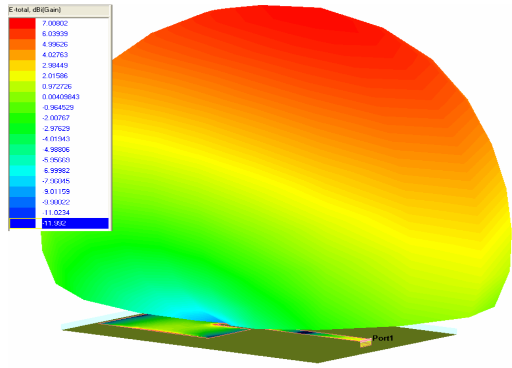


Figure 8. Current distribution and the radiation pattern of the rectangular microstrip antenna.

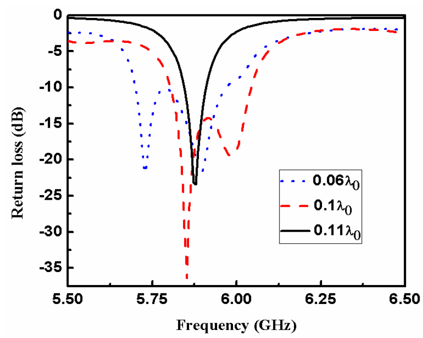


Figure 9. Parametric study of return loss of the antenna array with different spacing between the elements of corporate feed network.

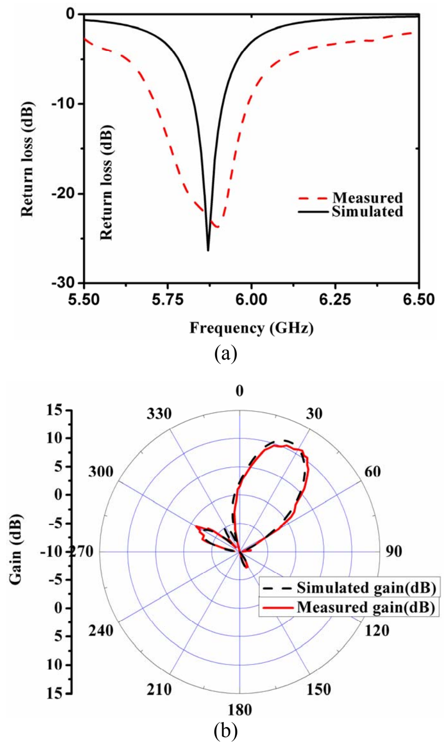


Figure 10. (a) Return loss of the antenna array; (b) Radiation pattern of the antenna array.

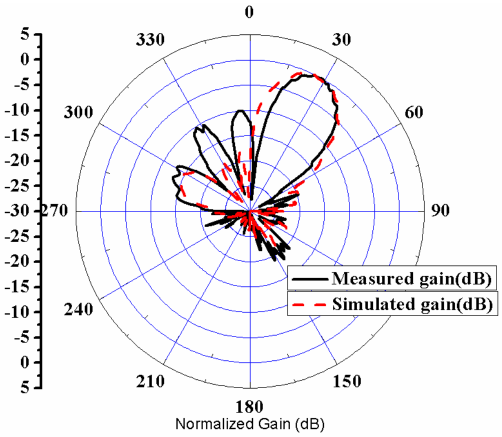


Figure 11. Normalized radiation pattern of the antenna array after placing it on the body of the car.

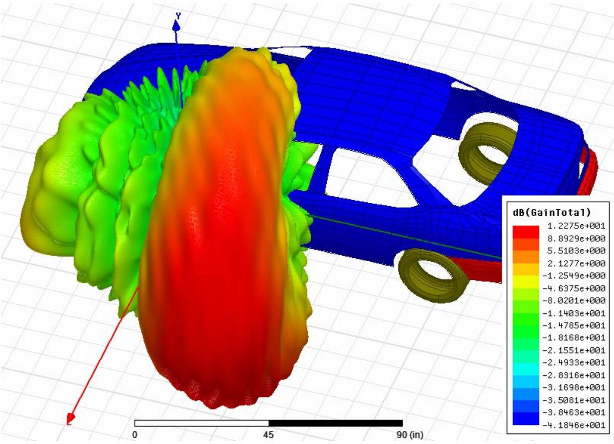


Figure 12. 3D radiation pattern of the antenna array after placing it on a vehicle body.

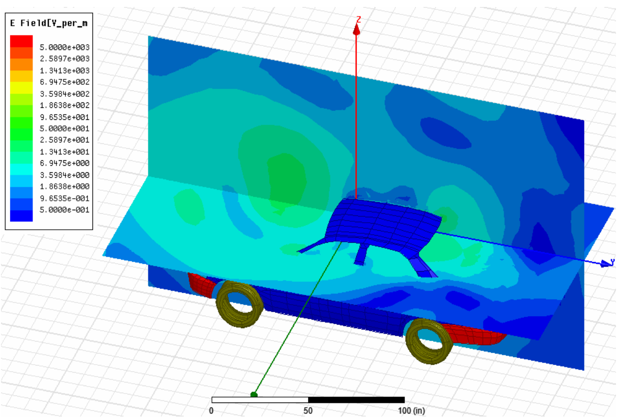


Figure 13. Inside electric field interference of the array after placing it on a vehicle body.

electromagnetic hazards.

5. Conclusion

A Tchebyscheff polynomial based microstrip phased array antenna is designed to detect the blind spot area of the intelligent mobile vehicle. The design is further simulated in Ansoft HFSS™ after placing the antenna on the body of the car and the results are observed. The result of the computational model of the entire antenna array is compared with the measured data before and after placing the said antenna array on the body of the car and found to be in good agreement. An overall 11 dB gain is obtained while measuring in the desired direction with minimum amount of electromagnetic interference inside the car.

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ABSTRACT

Now a day's accidents are very common due to increased population of vehicle. In order to ensure safety measures in the vehicle this paper has proposed some methodologies regarding careful driving by automatically scanning and analyzing the blind spot area of an intelligent mobile vehicle. A vehicular antenna with minimum perturbation is proposed to be fitted on the vehicle and collect information of the concern area which would ensure visibility of the operator *i.e.* masked or integrated within the car body. This paper has dealt with the design of Tchebyscheff polynomial based prototype planar microstrip phased array antenna and also redesigned the same when implemented in the body of the car being considered as an electromagnetically large element. Both the design has been experimentally verified with the measurement. The simulated and the measured results in both the cases are found to be in good agreement. More than 11 dB gain was observed at perfectly 30° angles from its broad side direction as desired for blind spot detection with minimum amount of electromagnetic interference inside the car.

Keywords: Intelligent Transportation System; Microstrip Phased Array Antenna; Tchebyscheff Polynomial; Electromagnetic Interference

1. Introduction

Intelligent Transport System (ITS) ensures mobility comfort and safety in transportation system. It also absorbs the hazards due to environmental impact. With the progress of the information processing technology, control systems to minimize accidents for the roadways have also been advanced hence one approach to improve the traffic safety is found and that is automatic collection of data by scanning the blind spot area of the vehicle [1] as shown in **Figure 1**. Many methods were proposed to detect the blind spot area but all of them had certain limitations. Devices like dynamic angling side view mirror [2], side view camera model [3], and shadow or edge features detector [4] were used for detecting blind spot area but their performance was affected during bad weather, fog or mist. Also we know that the mechanical systems, response time is more and the system is prone to wear and tear.

A radio frequency method has been proposed in this paper to scan the blind spot zone efficiently. Four rectangular microstrip antennas (RMSA) are arranged in linear configuration with optimal spacing between the patch elements to construct the phased array radar. A corporate feed network is used to feed the patch element unequally and a progressive phase shifter is designed with 108˚ delay elements to tilt the main beam in the desired direction and then the total unit is simulated and experimented after placing it on the car body which is electromagnetically a large element. The antenna works in the Dedicated Short-Range Communication Service (DSRCS) frequency band [5]. The design of the microstrip phased array antenna is discussed in Section 2 and after that to place the antenna; the design of the entire car is given in Section 3. Results and discussion are portrayed in Section 4 along with conclusion in Section 5.

2. Design of Microstrip Phased Array Antenna

The microstrip phased array antenna is designed for Dedicated Short Range Communication Service at 5.88 GHz with dielectric constant of 2.32 and substrate thickness of 0.785 mm. Firstly the dimension of the rectangular patch is computed as 16.322 mm by 19.8 mm using the method outlined in [6]. With computed inset feed length of 3.8 mm and for the above dimensions of the rectangular patch the return loss is found to be –8.09 dB

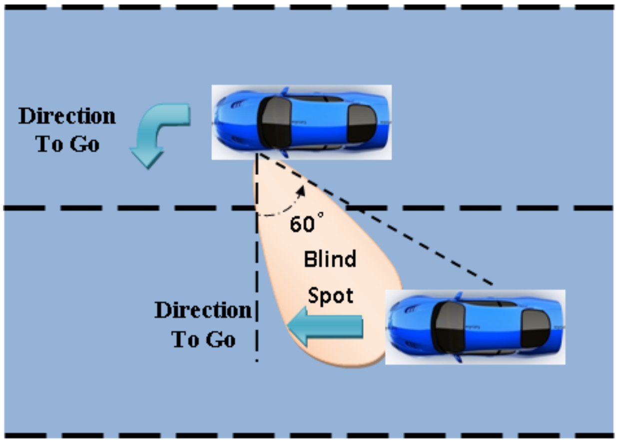


Figure 1. Surrounding regions of a vehicle.

with (30.1 + j26.7) ohm impedance at the feed position. The RMSA is simulated and optimized using Ansoft HFSS^{TM}. After optimization the final length is found to be 16.4363 mm with inset feed length of 4.8225 mm keeping the width of the patch unchanged as shown in **Figure 2**.

By considering the above designed patch element, a four element linear array is realized and powered by Tchebyscheff current distribution. The spacing between the elements is kept considering the desired maximum scan angle in order to eliminate the grating lobes within the visible space of the phased array antenna. To optimize the performance of the antenna in respect of its side lobe level (SLL), mutual coupling and gain of the antenna array, the spacing between the elements is studied parametrically [7]. The results of the said study are tabulated in **Table 1**.

After optimization it is found that the optimum spacing between the elements is 0.6 λ_0 while considering, the main lobe to side lobe ratio below 20 dB, optimum mutual coupling and overall gain.

From **Figure 1**, it is observed that the beam of the antenna array is required to be tilted by an angle 30˚ away from the broad side direction. In view of the above a progressive phase shifter of –108˚ is designed with the help of 11.16 mm feed line length. The actual line length is considered as mτ, where m = 0, 1, 2, 3.

To enhance the gain by maintaining the beam width and main lobe to side lobe ratio, the antenna elements are excited by Dolph Chebyshev current distribution. The array consist of four elements, thus third order Tchebyscheff polynomial is calculated. Hence the polynomial is solved and relative current ratio is computed as 1:1.7795:1.7795:1. Both equal and unequal power dividers are designed along with the progressive phase shifter.

For equal power division, a 3 dB equal power divider is designed whose vertical arm is of 50 Ω line and two horizontal quarter-wavelength branch-lines are of 70.71 Ω is used [8]. It is shown in **Figure 3(a)**.

Table 1. Effect on mutual coupling and gain due to variation in spacing (d) between the elements.

d with respect to guided wavelength	d with respect to operating wavelength	Mutual coupling (dB)	Gain (dBi)
0.6 λ_g	0.41 λ_0	>10	7.6
0.7 λ_g	0.48 λ_0	>13	9.9412
0.8 λ_g	0.55 λ_0	>20	10.647
0.9 λ_g	0.6 λ_0	>22	10.919

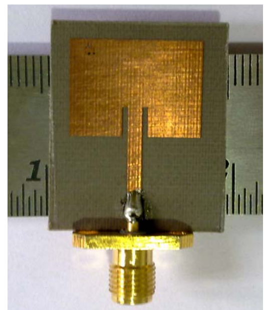


Figure 2. Photograph of the rectangular microstrip antenna element.

To get the unequal current distribution, both the horizontal arm of the microstrip unequal power divider should be of different resistance and it is calculated as 46.368 Ω and 82.49 Ω. The structure is shown in **Figure 3(b)**.

Generally for practical design purpose the gap between the corporate feed networks is taken small but the value of the gap less than 0.11 λ_0 disturbs the frequency response of overall antenna array. The effects of the feed network on the side-lobes are significant in the E-plane pattern. The influence on the H-plane is less important due to the orthogonality of the drive current and the symmetry of all the other currents in this cut [9]. By maintaining the SLL and the surface wave loss, the gaps are taken as 0.11 λ_0 as portrayed in **Figure 4**.

3. Placement of Antenna on the Vehicle

In order to compute the electromagnetic effect of the body of the car on the antenna performance, the entire structure of the car is designed in Ansoft HFSS^{TM}. The complete structure of the car consist of hood, roof, trunk, left and right side doors, left and right side quarter panel for front and rear side which are made up of conducting material but the bumpers and wheels are assigned by layered impedance due to their hard rubber and polyester materials as shown in **Figure 5**.

After going through the typical requirement for scanning the blind spot, the antenna is placed just beside the side view mirror. The following problems in the designed are addressed while simulating the effect of the radiation

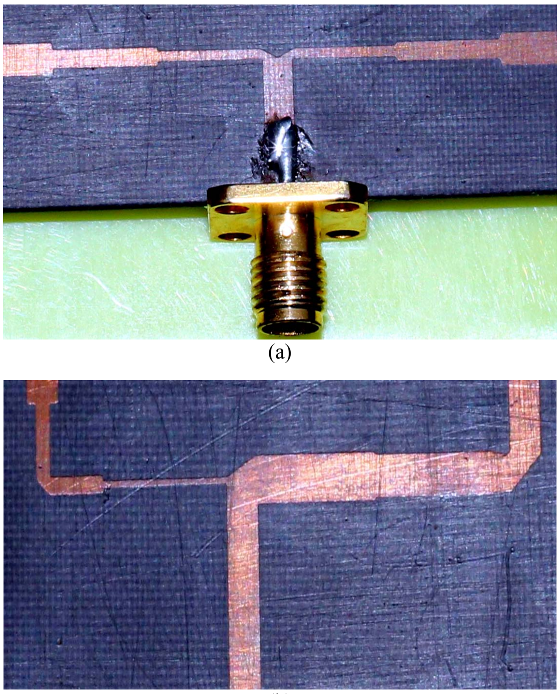

(a)
(b)

Figure 3. (a) Photograph of the equal microstrip power divider; (b) Photograph of the unequal microstrip power divider.

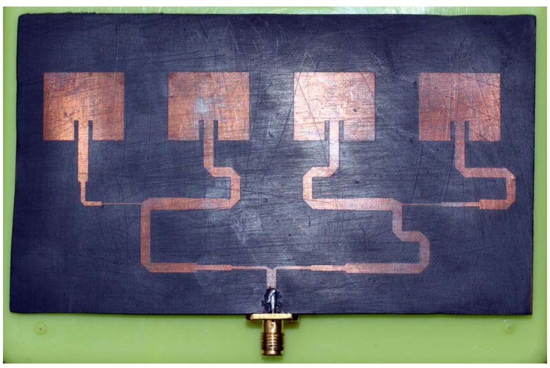


Figure 4. Photograph of the antenna array with corporate feed network.

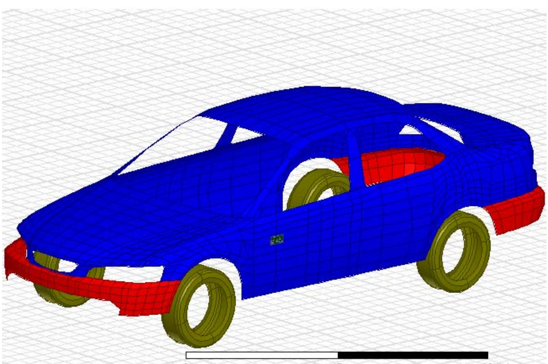


Figure 5. The entire structure of the car along with the antenna array.

characteristics of the antenna after placing it on the vehicle:

1) Spans a large computational domain compared to the wavelength;

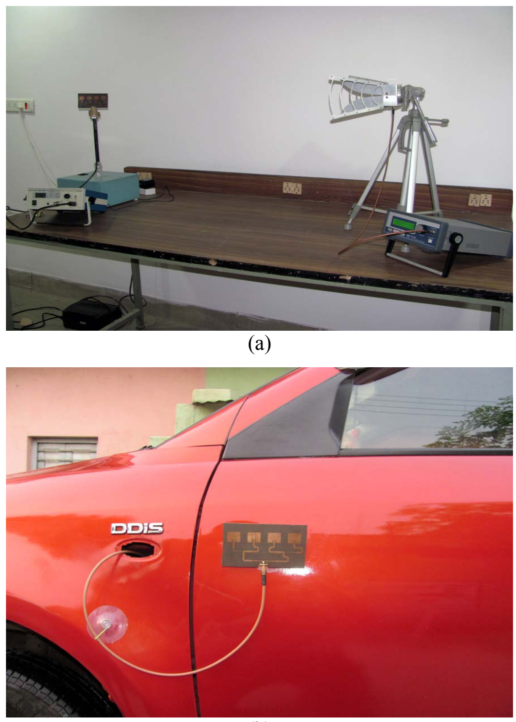
2) Requires a fine grid resolution to resolve the detailed antenna structure;

3) Contains largely non-conformal PEC and dielectric structures.

4. Results and Discussion

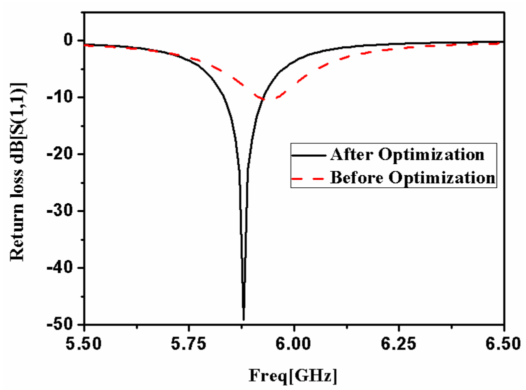
For obtaining the scattering parameter characteristics, the microstrip antenna has been simulated over the frequency bandwidth ranging from 5.5 GHz to 6.5 GHz and two different circumstances is observed. The first experiments involve the design, simulation and measurement after fabrication of an individual element and then the array with the same without involving the effect of the car. Both of them should used for optimized performance.

The scattering parameter is measured by Agilent Technology Vector Network Analyzer model no. N5320A (10 MHz - 20 GHz) and the radiation pattern is measured by Hittite HMC-T2100 synthesized signal generator (10 MHz - 20 GHz) and Krytar 9000 B power meter (10 MHz - 40 GHz) with 9530 B power sensor (10 MHz - 20 GHz) as shown in **Figure 6**. From **Figure 7**, it is found

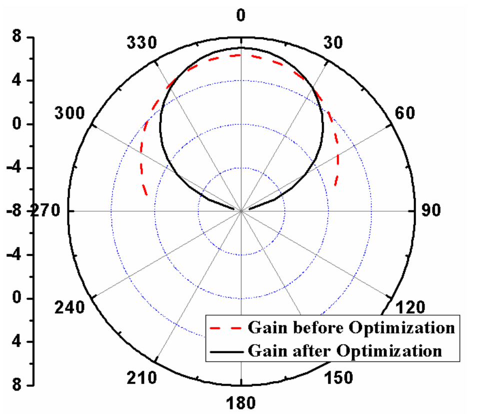


(a)
(b)

Figure 6. (a) Experimental set-up to measure the radiation pattern of the antenna array; (b) Experimental set-up to measure the radiation pattern of the antenna array after placing it on the car.



(a)



(b)

Figure 7. (a) Return loss a single patch before and after optimization; (b) Gain of a single patch before and after optimization.

that after optimization a perfect match is obtained exactly at 5.88 GHz and gain is also improved from 6.33 dB to 7.01 dB with a very good return loss of –47 dB. The current distribution and the radiation pattern of a single RMSA is portrayed in **Figure 8**.

A parametric study of the return loss of antenna array with different spacing between the elements of the corporate feed network is done and is compared in **Figure 9**. The results of the computational model of the entire antenna array with feed network were compared with the measured data and a good agreement is observed in **Figure 10**.

After getting the satisfactory results, next the same array antenna is experimented again with considering the electromagnetic effect of the car. In order to test the antenna array in association with the vehicle, a numerical model of the car is created using Ansoft HFSS^{TM} and the simulated data is compared with the measured in **Figure 11**. **Figure 12** graphically represents the 3D radiation pattern of the antenna array in presence of the computational model of the vehicle. From **Figure 13**, it is clear that the inside electric field strength is not more than 15 Volt per meter which is very less compare to the standard

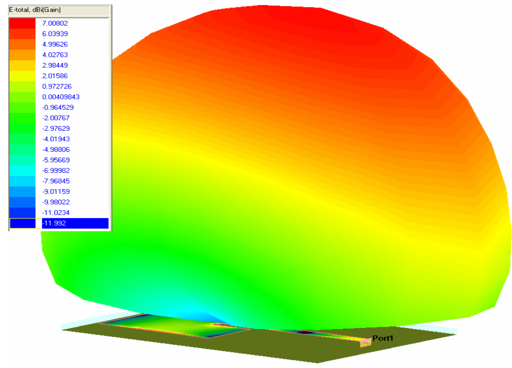


Figure 8. Current distribution and the radiation pattern of the rectangular microstrip antenna.

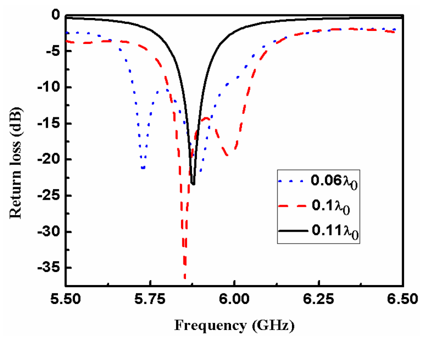
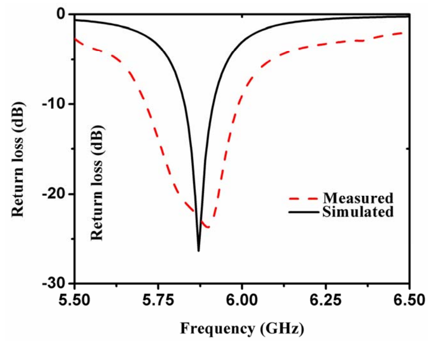
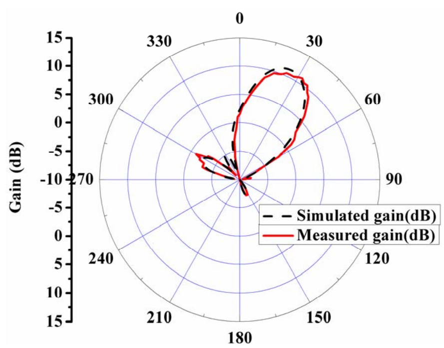


Figure 9. Parametric study of return loss of the antenna array with different spacing between the elements of corporate feed network.



(a)



(b)

Figure 10. (a) Return loss of the antenna array; (b) Radiation pattern of the antenna array.

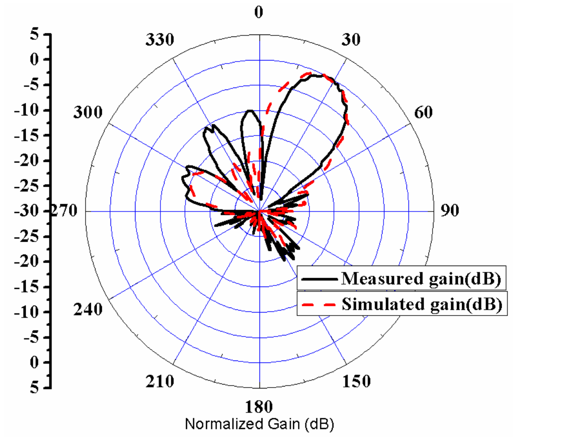


Figure 11. Normalized radiation pattern of the antenna array after placing it on the body of the car.

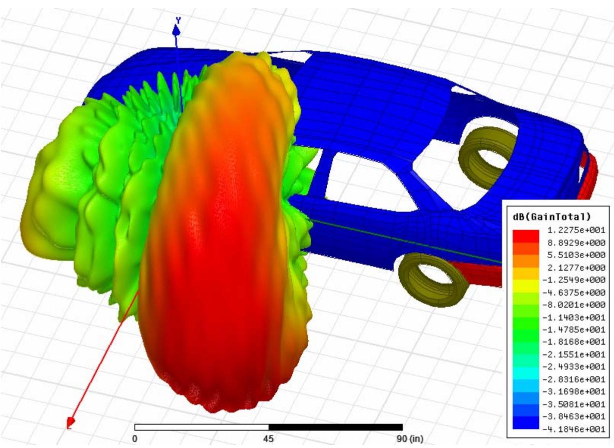


Figure 12. 3D radiation pattern of the antenna array after placing it on a vehicle body.

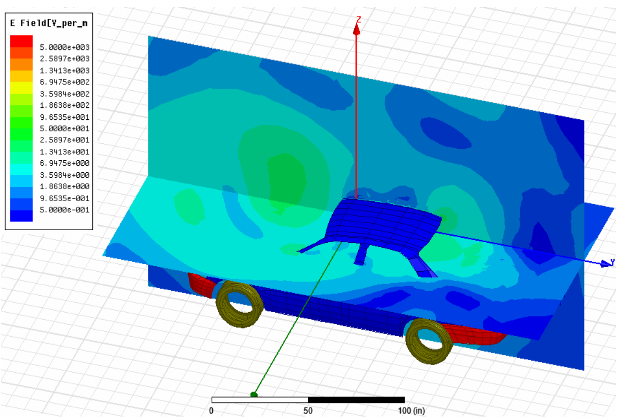


Figure 13. Inside electric field interference of the array after placing it on a vehicle body.

electromagnetic hazards.

5. Conclusion

A Tchebyscheff polynomial based microstrip phased array antenna is designed to detect the blind spot area of the intelligent mobile vehicle. The design is further simulated in Ansoft HFSS™ after placing the antenna on the body of the car and the results are observed. The result of the computational model of the entire antenna array is compared with the measured data before and after placing the said antenna array on the body of the car and found to be in good agreement. An overall 11 dB gain is obtained while measuring in the desired direction with minimum amount of electromagnetic interference inside the car.

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My Regenerative Shortwave Radio Project

A comprehensive story containing historical, educational, technical and biographical elements & opinions
by
© John Fuhring

Introduction

Please note that the following is a STORY or, if you will, an E-book that I wrote for my entertainment and in the hope that you will be entertained and maybe even encouraged to build something too. I do not make YouTube videos because I want people to read and think about things. I want people to learn from my experiences at their own pace and this can't be done with everything whizzing by in a video.

So, this is the story of how I came to build a shortwave regenerative radio and is given to you free and without advertisements. The project was started on a kind of a whim when I discovered the chassis of an old project in my junk box and then proceeded from there -- mostly through a long series of trial and error -- with lots of errors -- before I settled on a good Armstrong type design. This story has a lot of technical detail in it and it can be instructive, but I would ask you to please treat this article as a story because it is really meant to be read for entertainment and not as a construction manual.

If you think you might like to build a similar project and have any questions, please send me an E-mail using the link at the end of this story. You might want to know that there is a kit available that is almost identical in its design to my radio's design. I don't sell or advertise, but you can easily find the company that makes it by doing an Internet search.

As a project to be built up from scratch by beginners or young people, I absolutely **DO NOT**

recommend the "Scout Beginners" radio I describe in the story or even the Armstrong shortwave radio I will present in the latter part of this story (unless it is bought as a complete kit), but rather I recommend my Armstrong "Crystal" Radio. The Armstrong "Crystal Radio (or its good looking brother, the Geezerola Senior) is fun, cheap, quick and easy to build and it performs hundreds of times better than a straight crystal radio possibly can, especially with a short antenna. If you are interested in building a very simple shortwave regenerative radio, you might want to consider experimenting with the coil of my Armstrong "Crystal" Radio, but with fewer turns for shortwave. I think it is important for young people to build something simple enough that they can easily understand it, but that performs well and will be something that they will be proud of 50 years from now as I am of my first Armstrong radio.

If you are an experienced builder, this might be the ideal project for you to think about.

Anyway, here is the story of how I came to start this project and of all the things that happened before I finally ended up with something that I liked. I hope you find this story entertaining.

This story can be divided into the following chapters. You may not be interested in reading all of them in sequence, but if you are here for the story, I suggest you do read them in sequence.

Read what you want, it's free and without advertisements or anything for sale. If you like the story, please sign my guestbook or email me directly. Also while you are here, check out my other radio stories and essays listed at the end of this story.

Chapter 1
Why build yet another radio and what got me started

During the last couple of years, starting in 2011, I've been restoring old radios and completing old projects that were put on hold back in my high school days 50 years ago. This

activity has rekindled my old passion for radios and now I'm hooked once again. If that weren't bad enough, I suddenly got the itch to begin building radios from scratch once again. What could be a better way to begin than to begin at the beginning with something really basic and build a direct conversion receiver or maybe an Armstrong type regenerative radio?

Well, that's what I ended up building, an Armstrong type regenerative radio, but unlike the regenerative radio I built in 1958, this time I decided to use 1970s technology instead of 1920s technology and use a Field Effect Transistor (FET) in place of the venerable old 1H4 thermionic tube that I used as the detector of that early project.

My FET regenerative radio project.
Notice the really neat little tuning dial. Boy, they sure don't make nice ones like this anymore. It just begged me to make radio using it. Using a shortwave receiver, I listened for the regenerative signal when the unit was in oscillation and by matching my dial to the radio's dial, I was able to put calibration marks on the dial face (not shown in this photograph).

To tell the truth, the thing that triggered this latest project was finding a little chassis box while rummaging through my big box of radio junk This collection of junk is from old projects -- mostly from my college days. In there I found this excellent little box with a tuning capacitor and a wonderful dial mechanism already mounted on it. The box was from an abandoned project that never worked very well, but just looking at it got my "creative juices" flowing once again.

The box and its dial looked as "cute as a bug" and I remembered how, back around 1970, I had intended it to be a direct conversion receiver and the companion for the 80 and 40 meter

ham band transmitter I had just made. Direct conversion receivers can really perform well, but this one was a failure. No matter what I did to protect them, the delicate and expensive dual gate FETs I used as a mixer kept failing. After a while I stopped trying to make this little radio work and just tossed the project into my growing junk box because by this time I had a much better receiver at my disposal.

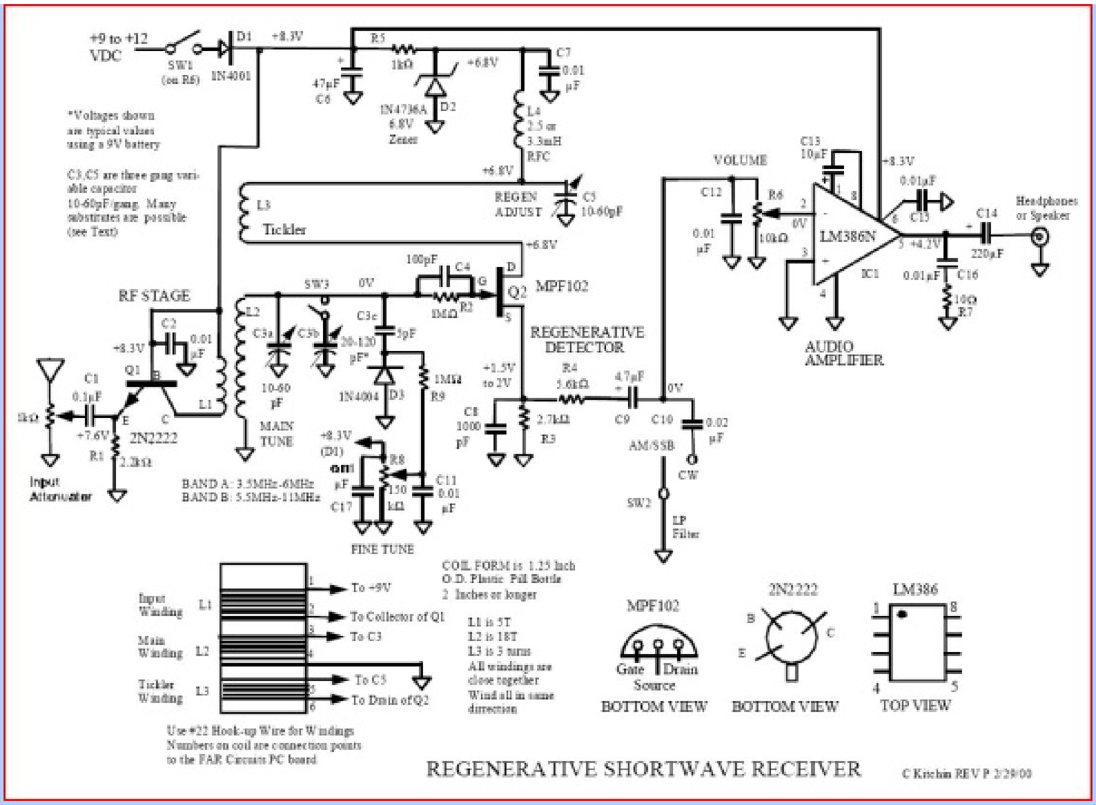
Now, when I opened the cabinet up for the first time in 40 years, I saw that the original circuit board was missing. I didn't care that I couldn't find the circuit board because it was built to an unreliable design and I wanted to build something better anyway. This then is the details of the evolution of my latest radio project from a Hartley bipolar transistor design that worked terribly to a Armstrong FET design that works great.

Chapter 2
Why reinvent the wheel?

So, there I was with this really neat little radio cabinet with its very nice vernier dial and tuning capacitor already installed and there it was just begging me to do something with it. The more I looked at it, the more " regenerative receiver --- regenerative receiver " kept popping into my head. I also considered building a direct conversion radio, but the fact is, a regenerative receiver can easily be used as a direct conversion detector simply by turning up the regeneration. A regenerative detector is much more robust than any dual gate FET mixer, it is very sensitive to weak signals and it will demodulate AM in addition to single side band and Morse code. So that settled it, this little box was going to be a regenerative receiver.

Of course I had several ways I could go if I built a regenerative receiver into this box. I could come up with my own design, breadboard it and experiment with configurations until I had a prototype that worked well or I could surf the Internet and see what smarter people have come up with and then steal their design. Being lazy, I chose the latter and found a rather nice circuit, designed by Mr. Charles Kitchen, that I really liked. After reading the article about the radio, I contacted a company on the Internet and ordered what I thought was the very circuit board mentioned in the article.

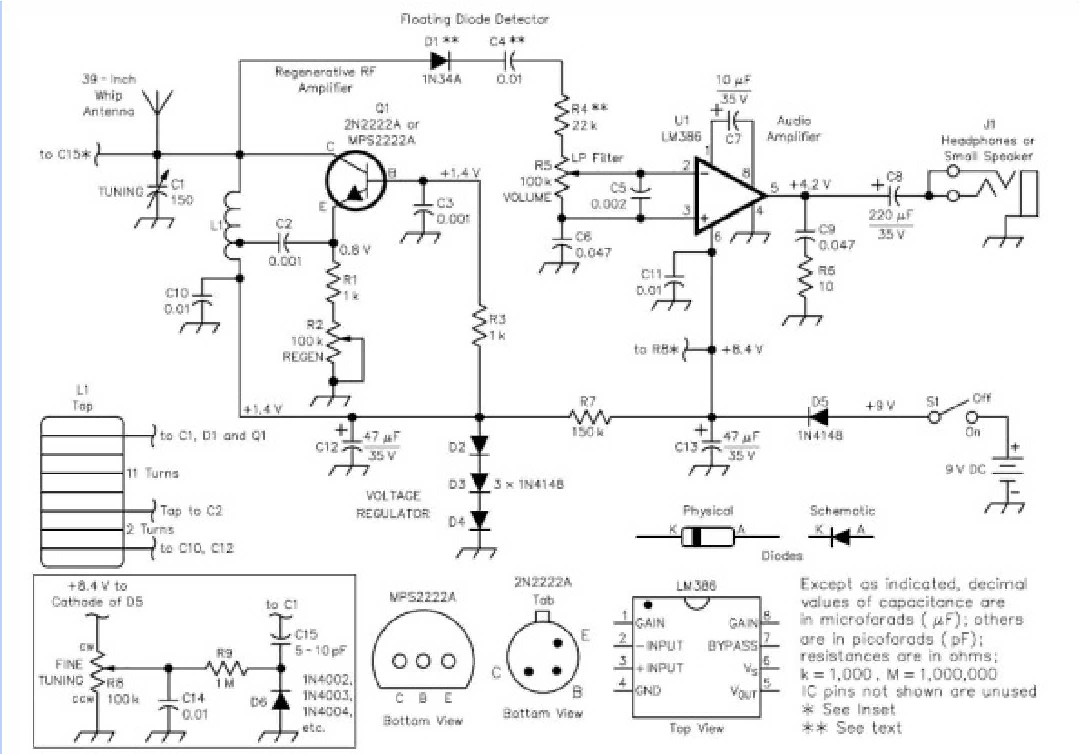
I though ordering a board was the best way to go since pre-made circuit boards are so much easier and faster than building a similar project on a " perf " board and the finished product is much more elegant looking than wiring up everything using the " dead bug " method. Don't get me wrong, the " dead bug " method is a perfectly good way to make stuff and I've make many things that have performed well, but all those " dead bugs " are so ugly, you just don't want anybody to see what you have built.



Charles Kitchen's FET Armstrong radio from the original article.

As I mentioned, Mr. Kitchen's design looked as good or better than anything I could design for myself so I eagerly sent off for the board and several days later something arrived. To my severe disappointment, they sent me a board for one of Mr. Kitchen's later projects called the "Scout Beginner's Receiver." To put it very mildly, I was extremely disappointed. At first I thought of sending it back, but the postage was so high that it equaled the cost of the board so I just fumed and stewed over it for a day or so. Finally I decided I'd give the design a try and see if it might be better than it looked.

Here's what they sent me:



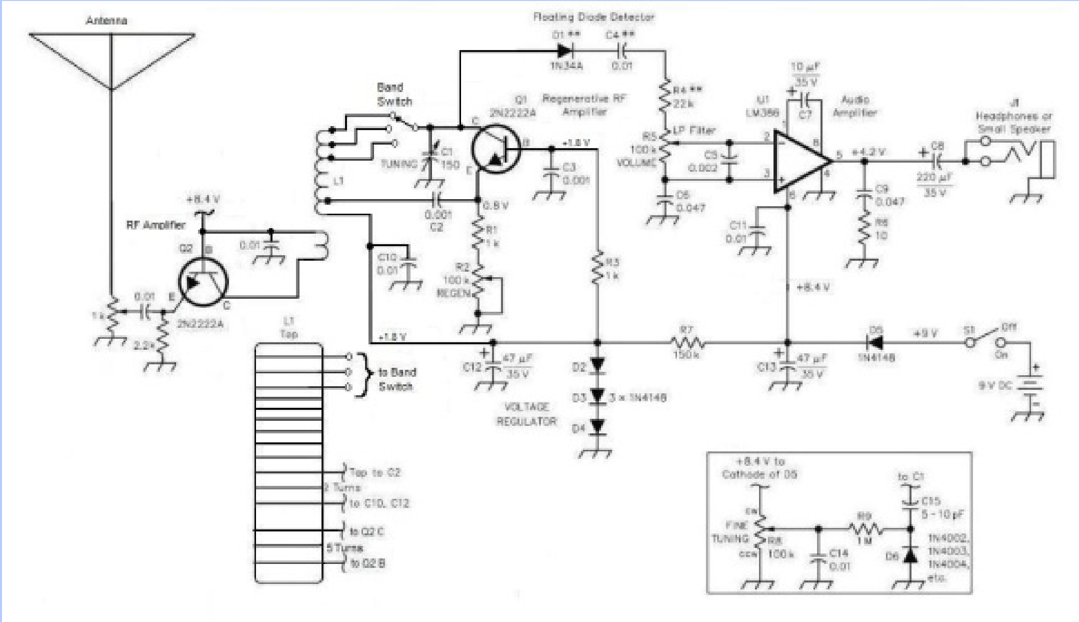
Mr. Kitchen's Beginner's Scout Radio with a bipolar transistor in a Hartley oscillator configuration.
What a disaster.
I'm sorry, but this design sucks!

There were several things that intrigued me about this "Scout" receiver. First, I had never worked with " common base" or "grounded base" designs before and you know, I still don't understand how they can amplify. Another thing, I had never used a bipolar transistor in a regenerative stage before, but had read that the amplification factor of a bipolar transistor in a regenerative receiver is actually much higher than for a FET (I have since learned that an element with too much amplification makes for very unstable regeneration control -- like this one had). Another thing that intrigued me was Mr. Kitchen's so-called " Floating Diode Detector. " I would have never believed that you could get away without a DC bypass of some kind, but there it was and I just had to try it. Finally, I had never seen a LM386 audio amplifier IC configured for high impedance like this and I wanted to see how well it would work.

I began stuffing the circuit board with parts and soldering them in. For a coil form I used a pill bottle I got at a pharmacy. When complete, I mounted the circuit board and all the other parts very neatly in my little aluminum radio chassis and turned on the set. Well, I could hear radio signals, but the truth is, the radio sucked. I mean, it sucked really badly (sorry Mr. Kitchen), I can't lie, it just sucked.

I was hoping I could get this disaster to somehow work without such "squirrellyness" so I decided to add an RF stage to its front end. After looking over the circuit board, I figured that I could easily grind out a portion of the circuit board's ground plane with a tiny diamond burr I have. That way, I could create the pads for an RF stage that I wanted. Well, I did, and it was easy to do and so I mounted a 2N2222 transistor for the RF amplifier and proceeded to put in all the parts for the other stages too.

Here's what I finally came up with:



My " improved " Beginner's Scout Radio.
I never did add a band switch, but otherwise I built it as shown.
It worked a little better than the original design, but oh did it suck!

First thing I noticed was that the RF amplifier stage worked OK, but the regeneration control was still ultra squirrelly and I mean **Squirrelly** with a capital **S**. When I'd tune in a station, the regeneration level would change drastically with the amplitude and it would sound absolutely awful. Now, when I bypassed the RF stage by turning it all the way down and I connected a short antenna to the tank circuit (as recommended in the original design), the regeneration worked somewhat better, but the signals were weak. When I tried using an outside antenna (by wrapping the wire around the short antenna, as recommended), the unacceptable squirrellyness of the regeneration returned. What a bummer! My feelings of disappointment returned with a vengeance and I was more than a little mad at Mr. Kitchen and that company on the Internet and at myself for wasting so much of my time on this turkey.

Chapter 3
I decide to scrap the original design
and here's a little rant you don't have to agree with

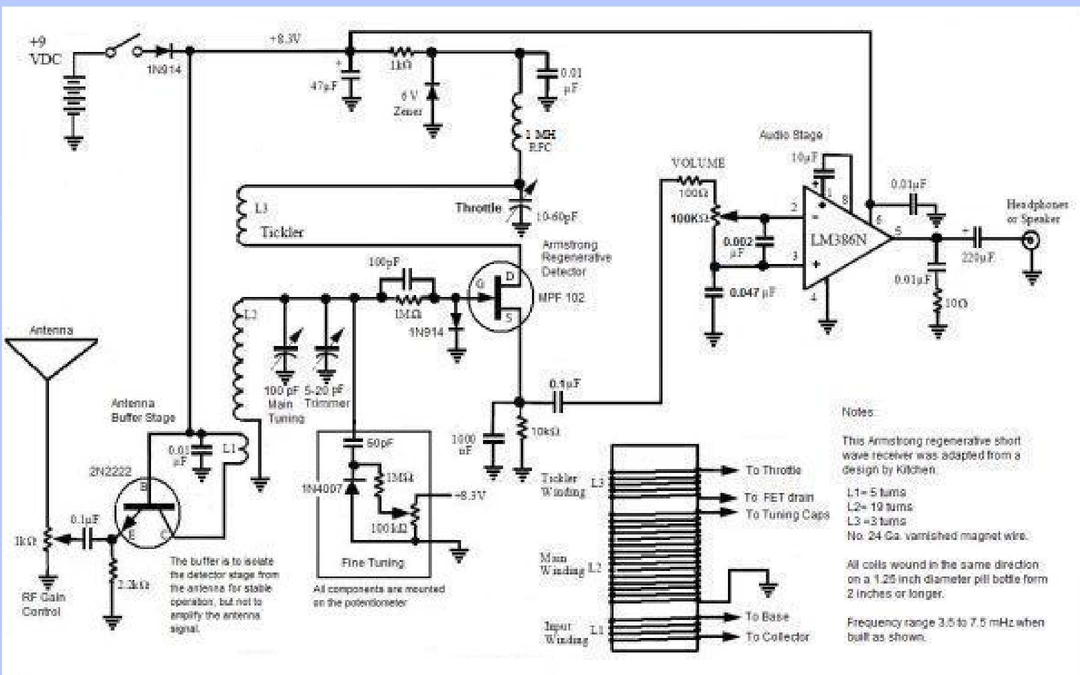
My radio worked so poorly, I just couldn't live with it any more and, as I mentioned, I was more than just a bit angry about all this. To tell the truth, I would never, in a million years, recommend that a young person build something like this. In my opinion, it is a waste of a kid's money, but more importantly, it has every potential to discourage a young person and turn them away from the whole idea of designing and building radios. Frustrating and disappointing projects have had that effect on me and I'm careful to avoid having young people feel discouraged. For example, I was given a cheap microscope as a kid and frustration and disappointment with it turned me off from the wonders of the microscopic world for nearly 50 years until I finally bought a really good scope. Overcoming adversities is a skill that all young people need to develop, but one shouldn't expect a kid to develop that skill too soon. In my opinion, this particular radio is not a good one for a young person to build because of the faults already mentioned and the fact that they would end up with something so utterly inferior, they would never be able to use it for anything practical or even want to

show it off. Again, I apologize to Mr. Kitchen and his friends for being so negative and for any hurt feelings, but I feel compelled to be honest here.

Chapter 4
You just can't beat Armstrong's original idea

After three days of trying every idea I could think of and changing the values of several of the components, I finally decided that I couldn't live with this design any longer. Well, maybe not all of the design, perhaps I could keep the RF stage and I could keep the audio amplifier stage, but everything else had to go and in its new incarnation, the regenerative detector would have to be an Armstrong type and I'd have to use an FET for the detector.

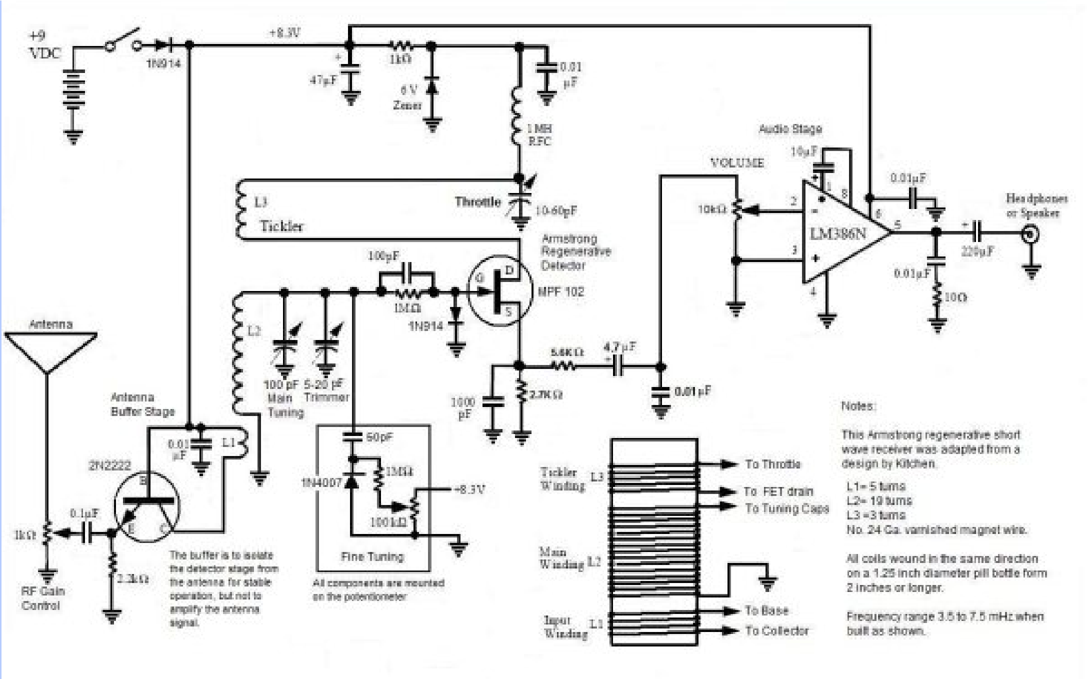
Looking over the circuit board, I formulated a way I could put an FET in there by removing some parts, adding others, grinding out a few traces and grinding in a few new ones. Actually, it was rather easy to convert the circuit board over to my new design and in a single evening I had all the modifications done. I put in all the parts and mounted everything in the little chassis as before. I even mounted a nice big (3 inch) speaker in the little chassis. Here's what my radio's schematic looks like now:



My Armstrong FET shortwave radio as it ended up being built.
Finally, I have a regenerative radio working the way I want it to.

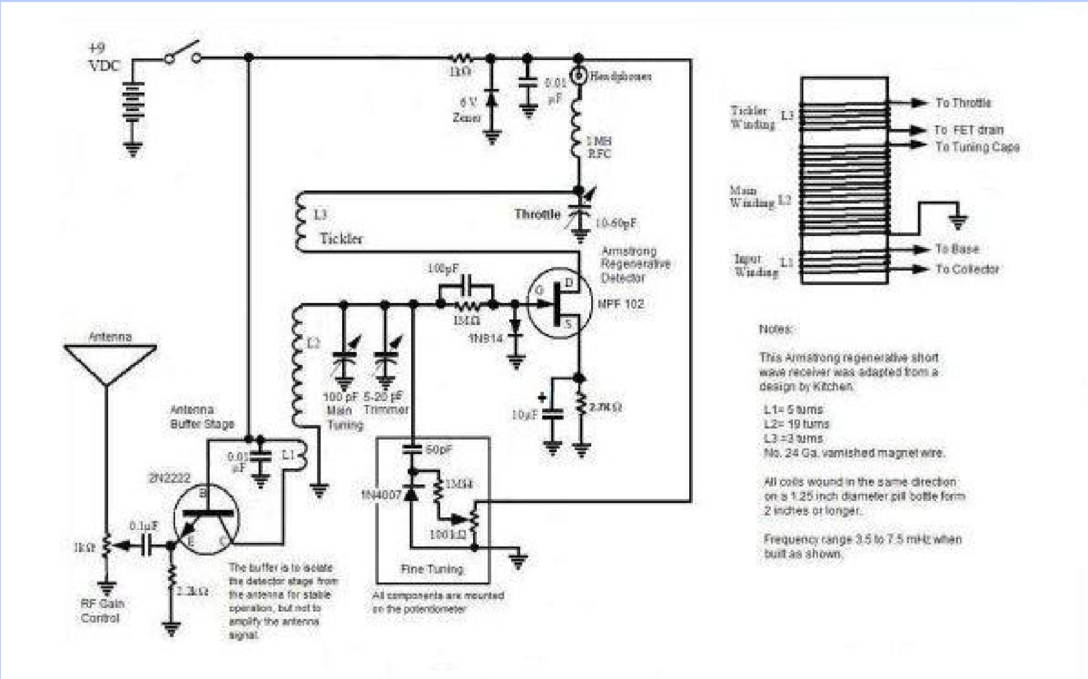
By the way:

If you decide to build a radio from scratch, this is the schematic I suggest you use.



An Armstrong FET shortwave radio with an
audio amplifier in a standard configuration.
E-mail me for a free larger schematic.
There is a company on the Internet that sells a complete kit very much like this.

Here is an even simpler version without an audio amplifier.



A simpler version of the Armstrong shortwave radio.
If you find that the audio isn't enough, an amplifier can be added later.
You will need to use a high impedance (>600 ohms) headset or earphone.
E-mail me for a free larger schematic.

What a huge difference in performance between the "Beginner Scout" and this Armstrong design. This particular design is stable, it sounds great and has much more volume than the other design. This radio really works well and I am extremely pleased with it. I have it adjusted to cover from 3.5 mHz to 8 mHz (or megacycles, as we used to say) and the tuning and regeneration control is smooth. The RF stage doesn't pull the detector and cause all kinds of unwanted regeneration effects like the NPN version did and even the volume control is nice and smooth.

Although I am using a really nice, very old dial with precision gear reduction, the tuning is so sharp that it is hard to get it right on frequency without a lot of trouble, especially on SSB. To overcome the sharpness of the tuning, I installed a really excellent little fine tuning control which uses an ordinary 1N4007 rectifier diode as a variactor. By the way, I built the fine tuning control on the potentiometer itself so that none of its components are mounted on the circuit board.

The circuit elements are as follows:
1) The RF stage, which uses a grounded base amplifier. The signal level goes smoothly from loud to soft as the RF Gain Control potentiometer's goes through its travel. I had expected a lot less linearity, so this control works better than I would have believed.
2) The Armstrong regenerative detector with its tickler coil and throttle is, of course, the heart of the project. The way it is configured, it is easy to tune, stable and fun to use.
3) An LM386 0.25 watt audio amplifier that is configured for a voltage gain of 200 (which is its maximum). As mentioned, it is arranged to be fed with a 100 K ohm potentiometer, which I've never seen done this way before, but seems to work just fine. I have it connected to an internal 3 inch speaker and it really pumps out the sound.

What Armstrong never had to put up with

You may have noticed that there is a subtle difference between the way this FET is configured and the way a thermionic triode tube (like my 1H4) is configured. After Armstrong figured out how the Audion tube actually worked (by thermionic emission of electrons and not by positive ions), he discovered that the grid would self bias and become negative due to picking up electrons from the stream that left the hot cathode on its way to the anode (plate). All he had to do was select a "grid tickler" resistor of sufficient value (like 1 or 2 megohms) that would allow the tube to self bias without becoming too negative. Too much resistance or an open circuit and the tube would self bias to cutoff, but too little resistance and the bias would be too small and the tube conduct too heavily and would be at the wrong part of its conduction curve for amplification.

With the FET, the equivalent "gate tickler" resistor shown will not have the same self biasing effect since there is no way for the gate to pick up passing electrons to become self biased. To bias the FET properly (make the gate "negative" with respect to the source (or cathode) and thus set the current through the FET to the right level), it is necessary to have a bias network between the source and ground. Biasing is accomplished by simply using a 10K resistor and a bypass 0.001 MFD capacitor. It just so happens that this is also a really excellent place to tap off the audio too. (By the way, you might want to experiment with a resistor between 5K and 10K in this circuit and determine for yourself what value works best when listening to SSB).

Speaking of the "gate tickler," people have asked me why I copied the original vacuum

tube configuration. I agree, with an FET instead of a vacuum tube, this network should be superfluous, but for reasons that are far beyond my understanding, this radio works very noticeably better with the gate tickler in there. The tuning is better, the regeneration control is better, the audio is better sounding and, as I mentioned, you can really notice it, but since it is so easy to bypass this guy, I invite you to experiment with this. If you come up with different results than mine and especially if you know why an FET behaves as it does under these circumstances, I'd really appreciate it if you'd write me at my E-mail address.

When listening to AM broadcast, the throttle should set the regeneration just slightly below the threshold of oscillation. At this level the FET is working at the correct bias, current flow through the FET is proper and everything is good. When the FET goes into hard oscillation, as happens as you tune to a higher frequency or when listening to Single Side Band (SSB) or Morse Code (CW), the FET conducts way too much and goes into a kind of run-away. The current through it is all wrong and it starts acting squirrelly and if the current rises too much and the voltage produced at the Zener diode looses regulation, it gets really, really squirrelly.

A self biased tube does not experience run-away under these conditions because the more it conducts, the more electrons the grid picks up and the more negative it biases itself. Because the gate of an FET can't pick up extra electrons and become increasingly negative like that, putting a high speed diode (the 1N914 shown in the schematic) in the gate circuit insures that extra negative bias will be automatically produced to keep the FET under control. With the diode arranged thus in the circuit, it allows negative bias to rise above the set value as oscillations gain in amplitude and thus the FET's current and operating parameters are kept where they should be. This diode works great to " de-squirrel " the operation of the radio when listening to SSB or CW signals and I recommend putting one in there. Of course, there are lots of diodes out there, but be sure you use a fast switching type in this circuit.

At least, that's what I think the 1N914 diode is doing to the gate circuit. I'm sure the smart guys who really know their theory will soon be setting me right about all this, so stay tuned for a better explanation why this diode in the gate circuit works so well.

Chapter 5
Back to the project
and some pictures

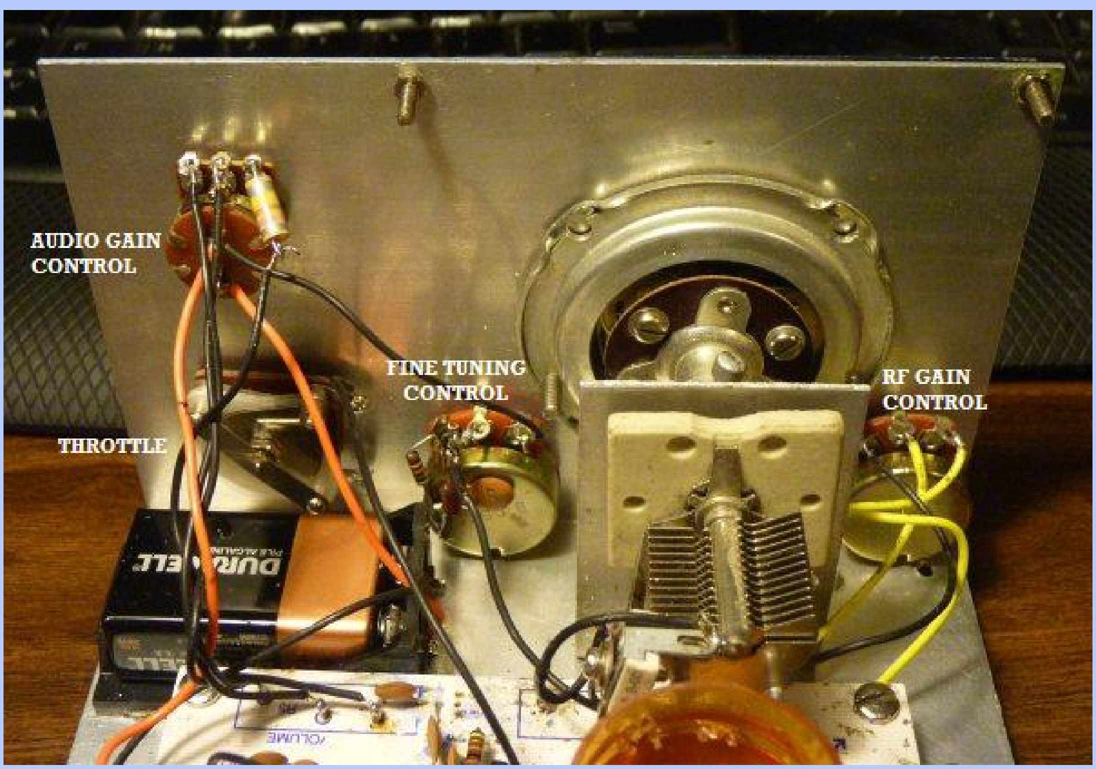
To protect all the circuits, I'm using a 1N914 diode to block reverse voltages in case somebody tries to put the battery in backwards while the set is turned on. Yes, the connections on top are polarized and normally you wouldn't have the set turned on when changing batteries, but I like to have my stuff fool-proof whenever possible. Why a 1N914 diode? I have a lot of 1N914s and they will easily handle the current, but any diode will work just as well. You have a lot of 1N4007 or 1N4001s? Yeah, they will work fine too.

Finally, I left the high impedance audio control potentiometer alone since it works smoothly throughout its range and the audio level in this configuration sounds just as loud as when using a more conventional 10 K potentiometer. I discovered that there was some kind of audio oscillation that started when the potentiometer was set all the way open, but that a small value resistor or choke coil easily eliminated it. I guess I should have added some RF filtering here, but a simple resistor in line with the potentiometer's high side works just fine.

As a future addition, I want to experiment with a band switch to short out some coil

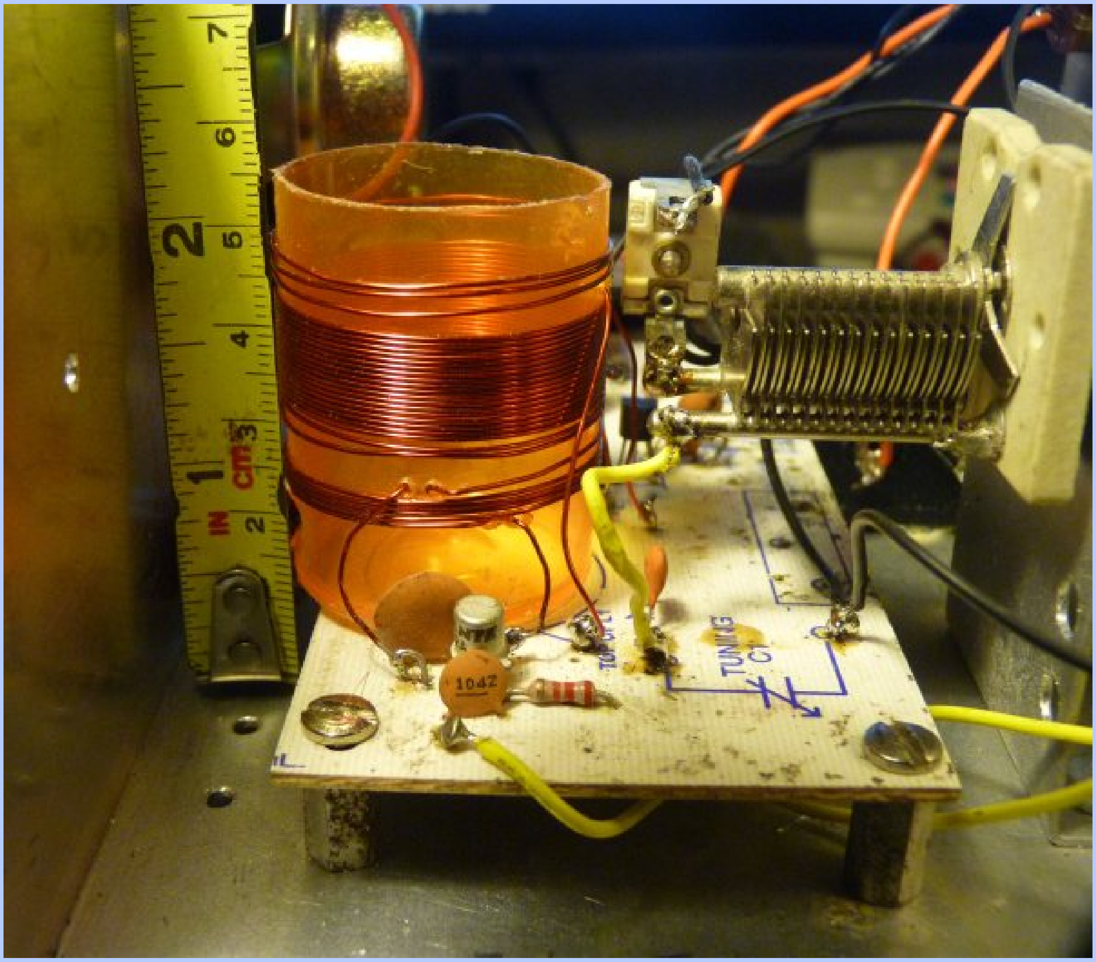
windings so I can extend the range of the set up to 15 mHz or so. I think it would be nice to have two bands, 3.5 to 8 and 8 to 15 that would be selected by a simple toggle switch.

Inside my FET regenerative radio project showing the
highly modified circuit board.
This is an early version without the fine tuning circuit.



A view from the rear showing the backside of the front panel.
The little choke soldered to the rightmost lug of the volume control

eliminates an audio instability.



A view from the side showing (top to bottom) the tickler, main tuning and signal input coils.

Chapter 6
Final thoughts on this project and some suggestions

Well, in words and pictures, that is the story of my latest regenerative radio project. If you are interested in building a similar radio, I suggest you follow Mr. Kitchen's advanced regenerative radio design but strictly avoid his "Beginner's Scout" design. It will help a lot if you can get the right circuit board for the project, but if you are careful and use those stick-on strips and pads, a perforated circuit board will work wonderfully for you. I have recently built several BFO's and HF buffer amplifiers using perf boards and stick-on pads and they work just great and look good too. If you have to, you can use the "dead bug" method where you use globs of solder to connect everything and it will work well at these frequencies too, only just don't show anybody the insides of your radio. It works, but god is it ugly!

Just added: Not long ago I discovered that there is a company that makes complete kits based on this design. I am impressed with the excellence of their kit and I think that they are pretty reasonably priced. I do not advertise for any commercial businesses, so I won't supply you with a link to them, but if you do a web-search on "scout regenerative radio" or qrpkits, you will easily find them. If you have a favorite chassis you want to build a custom radio into, you could simply discard their chassis and use your own or you could ask them if they would sell you a board and a partial kit -- they may not, but it doesn't hurt to ask.

Chapter 7
Credits
with some personal thoughts and philosophy you don't have to agree with

I'd like to thank the long deceased Edwin Armstrong for the many invaluable contributions he made that started the electronics revolution and especially for formulating the inventions behind most of the neat stuff I've built over the years. I'm sorry you lost your temper, hit your wife and jumped out of a window to your death, but I've been screwed by evil villains like David Sarnoff myself and I think I know a little of how you must have felt. If it means anything now, I too acknowledge the fact the U.S. Supreme Court was wrong, you were right, Lee Deforest was a fraud and he received way too much credit for things he never even understood. I'm sorry, but RCA was right about the need for FM to move up to the VHF high band. The truth is, some of those young engineers actually understood your invention better than you did. It happens all the time in high technology where us old guys get beat out by the whippersnappers and have to take an early retirement.

If I could, I would like to tell you about what I have discovered regarding money, recognition and happiness. What I've found is that there is no hateful person and certainly there is no amount of money or fame that is worth sacrificing your happiness, the happiness of those you love and especially your life for. Greedy, ruthless, scheming, manipulative bastards like Sarnoff may cheat you out of your money, the recognition you deserve and your plans for a better world, but they can take your happiness only if you give them the power to take it. We should never give those people that kind of power. Screw the money, the fame and the whole sorry lot; it won't buy you anything if you end up killing yourself or if, in your frustration, you hurt the ones you love. It doesn't take all that much to live comfortably and happily and, in the end, we all finish up dead and forgotten with no way to take it with us anyway. Naked you came forth from nothingness when you were born and naked into nothingness did you return when you died, not withstanding your accomplishments in life -- as shall we all in the end.

Now, having said all that and after thinking how pompous it was of me to write it, I have to qualify my remarks by admitting that I have always been a bachelor with no wife and no kids to make me a "hostage of fate." I realize that those who have much also have much to loose and for them I feel sympathy if they have come to believe that they are trapped in a situation where their family would suffer if they gave up that job that was otherwise killing them. If only intellectually, I know that responsibility is a heavy burden and only the self knows what things can, should or must be done to make that burden bearable. Toward the end of my career I was stuck working for an evil company who's primary business is to make evil, genocidal things, but I "stuck it out" because I wanted to save for an early retirement and stay in an area where I had property and friends. Fortunately for me, I had another world of horses and riding I'd step into after work and on the weekends and I refused to carry a pager or (later) a cell phone. If you really are stuck in a unhappy situation, I hope you find something similarly happy to do outside of that which makes you unhappy.

Finally, I'd like to apologize to Mr. Charles Kitchen for the mean (but true) things I said about his Beginner's Scout Radio. However, I'm not taking anything back. I do want to thank him for all the ideas that I shamelessly ripped off from him. I also want to acknowledge that most of the schematics I'm presenting here were originally drawn by him and that I only

modified them.

The End

Having arrived this far, obviously you have a superior attention span and reading ability that far exceeds that of the majority of web users. I highly value the opinion of people such as yourself, so I ask you to briefly tell me:

Did you enjoy this article or were you disappointed?

Please visit my guest book and tell me before you leave my website.

If you have any detailed comments, questions, complaints or suggestions,
I would be grateful if you would please
E-mail me directly

If you liked this article on a "modern" Armstrong regenerative radio, maybe you would like to read about

The first Regenerative Radio I ever made
that tunes the broadcast band

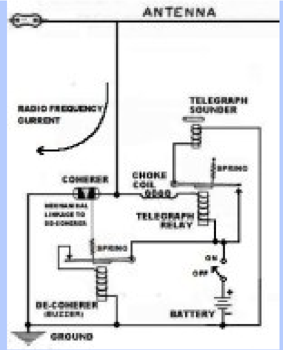
After 55 years, I have just built a radio based on the same design as my first amplified radio but this one uses a little booger of an FET instead of a big beautiful vacuum tube.

An Armstrong "Crystal" Radio
from "The Old Geezer Electrician"

If you are looking to build something with the same great performance of these little regenerative radios, but looks a whole lot nicer, I would like to suggest

The Geezerola Senior radio

Or perhaps you'd like to read my essay on



Early Coherer and other radio detectors.

Or maybe the article on my

High performance Heathkit CR1 crystal radio.

I have made a working prototype of a small and cheap crystal radio based on the Heathkit CR1

A crystal radio project for advanced students and hobbyists

If you like reading about building home made radios up from scratch, perhaps you would like

My Magnum Opus homebrewed ham radio project

I have many other radio articles on my website, so perhaps you would like to

Select some other radio article

from my list of interesting old radios.

Or, you can try to find something interesting searching around on

My Home Page

The Philco Portable Radio Project

A nostalgic World War Two era battery portable radio built for the real Summer of '42.

A comprehensive story containing historical, educational, technical and biographical elements & opinions
by
John Fuhring

Please note:

It has come to my attention that visitors looking for the story of what I call my "Fireside Chat Radio" are being directed by the search engines to this story. I really like the story about my "Summer of '42 Radio" and I hope you will read it, but what I call my "Fireside Chat Radio" is really my beautiful 1936 Fairbanks Morse Shortwave Radio.

Please note that I have stories about two other 1930s radios that were also used to listen to FDR's Fireside Chats: my 1936 Troy Radio and my 1937 Crosley Super 8 Shortwave Radio.

Finally, please note that all my rather long stories are just that, STORIES and were written for my entertainment and in the hope you would be entertained too. They are free, they are without annoying commercials and your privacy is respected.

Introduction

This radio was given to me sometime in 1961 by one of my mother's friends. I wasn't home at the time, but my younger brother remembers when the radio was dropped off for me. It is a hansom battery portable radio with a roll top and even today it looks beautiful. For reasons I'll discuss below, it almost immediately went into storage in my brother's closet where it rested for 50 years.

When I was first given the radio it didn't work. It had a burned out detector tube and I had no idea where I'd get a replacement for it. Most importantly, the radio didn't have a shortwave band, so I really wasn't interested enough in it to start trying to fix it. Besides that, I didn't have a schematic diagram of the radio and back then, a schematic would have been nearly impossible to get. Only now, thanks to the Internet, are schematics and repair manuals available. Again, thanks to the Internet, replacement tubes are readily available too. By the way, I ungratefully failed to acknowledge the gift or thank my mother's friend for her thoughtfulness. I wish now I would have because, short wave or no short wave, I really love this old radio.

Today this radio is a beautiful relic from the **real** Summer of '42 when people who were young and alive then went on picnics and outings with their battery operated portable radios and enjoyed the peace and beauty of the outdoors before the Second World War swallowed it all up and then left us with the Cold War with all the terrible rumors of Nuclear War that followed.

The radio with the top up, operating on batteries and tuned into KGO in San Francisco.

Here's the radio with the front rolled down ready to be taken on a trip to the beach or to a picnic.

What it looks like from the back. Notice the nice woodwork.

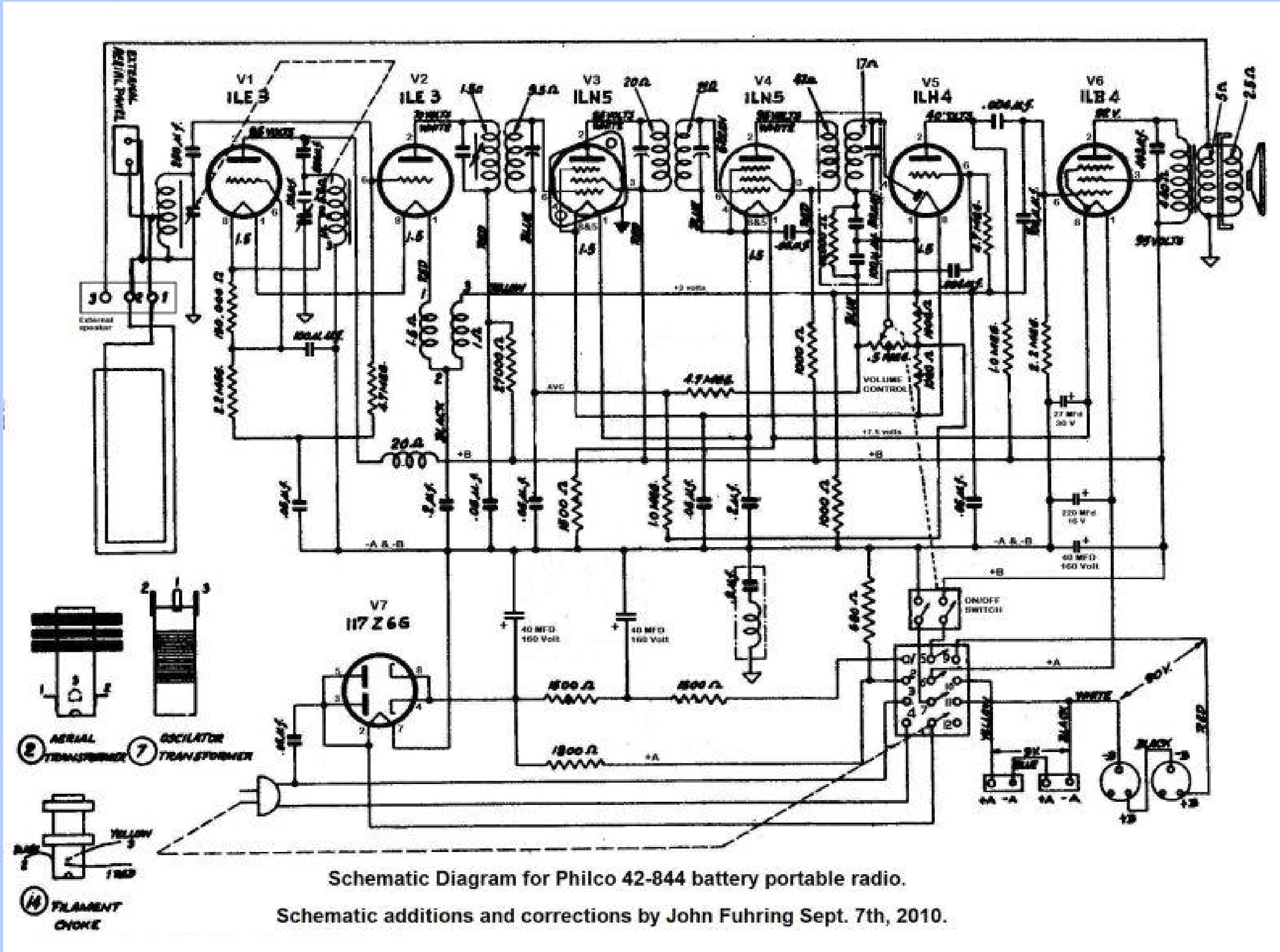
With the rear open you can see the dry cell battery pack under the main chassis, the ac plug inserted in the "battery operation" position, the 5 silver colored receiver tubes on the left and the black rectifier tube on the far left. The wires going around the inside of the radio case is the loop antenna for pulling in AM stations. A label on the back suggests using this radio to receive the sound while watching early, pre-war, television.

These were rather expensive radios for their time and worth about $400 in today's money so only the rich and elite would likely own one. Only about 1,500 of these radios were ever made and I wonder how many of them survive to this day. I suspect that I have one of the nicer ones and mine is complete with a battery pack I made up from 9 volt transistor batteries that allows me to play the radio either plugged in or portable.

Speaking of batteries, this radio was made by the Philco Radio Battery Company. In the early 1920's the Philco company made a good living making batteries for the early radios of that era because the early radios really ate up batteries. That's all Philco made at the time but by the mid 1920s the first AC rectifier tubes started coming out along with the development of electrolytic filter capacitors and that doomed radio batteries to a small niche market. There were still battery operated radios on farms that didn't have electricity and early portable and military radios, but the market was shrinking fast. Rather than go out of business, Philco reinvented itself and began to make good, high quality, but very affordable radios. Old brands like the super quality Atwater Kent's did not want to cheapen their name, so they simply decided to stop selling radios and go out of business. With the passing of the super quality radios, this left the radio market to such brands as GE, Motorola, Emerson, Zenith, RCA, Philco and about 500 other lesser known brands. Of all the brands, the Philco radios stayed very popular because they were well made, very good looking and relatively cheap.

I said "relatively cheap" because these radios were expensive by today's standards. All radios sold before the late 1950s, regardless of quality, had to be hand made and each of their many, many expensive electronic components had to be hand soldered in by trained technicians in a very labor intensive way. Even the cabinets housing these radios were elaborate wooden or Bakelite designs that had to appeal to the buyer and all that added up to a rather pricey consumer item. There were radio stations everywhere and the marvelous entertainment they provided people back then before TV and personal

computers made their price well worth it. The poorest families owned at least one radio and everyone gathered around their set to listen to FDR's "Fireside Chats" reassuring everybody that they "had nothing to fear but fear itself" and this is what got a lot of people through the Great Depression and the anxieties of World War Two. The country was never so united or so culturally sound as during the heyday of AM radio.



Schematic Diagram for Philco 42-844 battery portable radio.

Schematic additions and corrections by John Fuhring Sept. 7th, 2010.

Like so many other schematics, I pulled this off the Internet and then redrew for clarity and ease of tracing down any problems with the operation of the radio.

Because this radio is designed specifically for battery operation, it uses low voltage "directly heated cathode" type tubes. This means that the filament is also the cathode of each of the tubes. Having directly heated cathodes means that the wiring of the heater circuits has to be somewhat complex than it would be in "indirectly heated cathode" designs It took a bit of figuring out how the filaments were wired up and switched around when I first started this project.

Of course, this radio uses RCA patents and is a superheterodyne design. The superheterodyne is what all modern radios are based on, but the concept goes back to when it was first developed during WW 1 by the brilliant radio engineer, Edwin Armstrong and patented by RCA. The first superheterodyne radios came out in the early 1920s when vacuum tubes were undergoing a rapid evolution, but only the best and most expensive radios (like the Atwater Kent radios) could afford to use this design and the fantastic new tubes the design required. By the late 1930s, the evolution of high performance and affordable vacuum tubes had come a long way and almost all radios were based on the superheterodyne.

The superheterodyne receiver circuit of this radio is somewhat unusual (and a little complex and actually rather old fashioned) because it uses separate triode tubes (1LE3's) for the local oscillator and the heterodyne mixer (AKA "the first detector"). The heterodyning to produce a 455 KC Intermediate Frequency (the IF frequency) is accomplished by having the filaments/cathodes of the two triode tubes coupled together by being in series with each other. In other words, the Local Oscillator signal from the first triode is coupled to the second triode through their filament circuits and mixes with the radio

station signal in that tube. This tube pair is isolated from the filaments of the other tubes by a rather unusual a double choke that is bypassed in the center by a capacitor.

This radio is further unusual in that it uses two tubes (both 1LN5s) in the IF amplifier stage instead of the usual single tube IF amplifier. Strangely enough, only one of these tubes (the one that is rubber mounted) is actually controlled by the automatic gain control (AGC) line. As unusual as it is, the radio pulls in AM stations quite well, although I think a simpler and more conventional pentagrid converter tube with a single IF tube would work just as well.

This radio went on sale late in 1941 for the summer of 1942. Curiously enough, a rear sticker suggests using the radio for listening to the sound of early TV broadcasts. There is a tap on the output audio transformer so that an external speaker can be connected and the radio can then be used to fill a TV room with sound. Of course, World War 2 quickly put an end to early television and commercial television didn't get started again until the mid 1950s. Sometimes I wonder just how far along TV would have come by the time I was a kid if WW 2 wouldn't have delayed it. I wonder if people would have been watching big screen color TV sets by the late 1940s?

As mentioned, I made up a battery pack for this radio consisting of several 9 volt transistor batterys in parallel for the 9 volt 'A' battery (to run the filaments) and several 9 volt transistor batterys in series to make up the 96 volt 'B' battery. I can tell you that either operating off AC power or the internal battery pack, this radio pulls in the stations, especially at night.

Sadly for me, I must also mention that the AM band is today a tragically sad remnant of what it once was. In the evening hours I listen to KGO up in San Francisco (810 KC on the dial) and it is as interesting and as wonderful a station as it has ever been, but the few local AM stations that remain are simply trash. This trash ranges from the absolutely ubiquitous and awful right-wing Hate Talk Radio to the equally disgusting right-wing Christian Radio preaching their messages of intolerance as if they were speaking for God and not their own twisted and goofy beliefs. It is such a disappointment to me that here in my area, there is absolutely nothing to listen to during the day time on AM. Well, that's not necessarily true, because there are two stations in my area that play Mexican music and listening to them is a whole lot more fun than listening to the sick propaganda and downright insanity that is being broadcast by people like Glenn Beck and Michael Wiener (AKA 'Savage') hour after hour after hour.

It is so sad to realize just what AM radio has degenerated down to, but AM radio is an extremely ancient entertainment media that has now become entirely obsolete and may disappear entirely within the next few years because people have so many other and better forms of entertainment to listen to and watch.

And you know the sun's settin' fast,
And just like they say, nothing good ever lasts.
Well, go on now and kiss it goodbye,
But hold on to your lover,
'Cause your heart's bound to die.
Go on now and say goodbye to our town, to our town.
Can't you see the sun's settin' down on our town, on our town,
Goodnight.
(Lyrics from "Our Town" by Iris Dement)

THE END

Having arrived this far, obviously you have a superior attention span and reading ability that far exceeds that of the majority of web users. I highly value the opinion of people such as yourself, so I ask you to briefly tell me:

Did you enjoy this article or did it suck?

Please visit my guest book and tell me before you leave my website.

If you have an antique AM radio and you need something decent to listen to, perhaps you should buy or build your own

Low Power AM transmitter

If you liked this article, perhaps you'd like the story of

[My very rare 1942 Farnsworth portable radio]

You might be interested in another World War Two era radio that was very popular with our troops and can still be found in places around the world where our GI's were stationed.

[My WW II Echophone GI's Shortwave Radio]

I have two even older and really wonderful radios from the 1930s you might like to read about.

[My beautiful Fairbanks Morse radio]

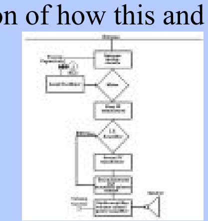
or maybe you'd like to read about

[My rare art deco Troy Radio and Television Company table radio.]

Recently I found and restored a 1938 Crosley Super 8 radio that was from a posponed repair job 50 years ago

[Please go to my Crolsey Radio Story]

For a simplified, but more in depth explanation of how this and similar radios work, you might be interested in



[An essay on the Armstrong Superheterodyne Radio Principle]

I have a lot of other stories about my antique radios and an essay on early radio detectors you might like.

Please select another radio article

If you are looking for something else, you might begin searching my
Home Page